photon focus

User Manual
HURRICANE CameraLink™ Series
CMOS Area Scan Cameras

MAN021 10/2005 V1.1

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1 Preface

1.1 About Photonfocus

The Swiss company Photonfocus is one of the leading specialists in the development of CMOS image sensors and corresponding industrial cameras for machine vision, security & surveillance and automotive markets.
Photonfocus is dedicated to making the latest generation of CMOS technology commercially available. Active Pixel Sensor (APS) and global shutter technologies enable high speed and high dynamic range (120 dB) applications, while avoiding disadvantages, like image lag, blooming and smear.
Photonfocus has proven that the image quality of modern CMOS sensors is now appropriate for demanding applications. Photonfocus' product range is complemented by custom design solutions in the area of camera electronics and CMOS image sensors.
Photonfocus is ISO 9001 certified. All products are produced with the latest techniques in order to ensure the highest degree of quality.

1.2 Contact

Photonfocus AG, Bahnhofplatz 10, CH-8853 Lachen SZ, Switzerland

Sales	Phone: +41 55 451 01 31	Email: sales@photonfocus.com
Support	Phone: +41 55 451 01 37	Email: support@photonfocus.com

Table 1.1: Photonfocus Contact

1.3 Sales Offices

Photonfocus products are available through an extensive international distribution network; details of the distributor nearest you can be found at www.photonfocus.com.

1.4 Further information

For further information on the products, documentation and software updates please see our web site www.photonfocus.com or contact our distributors.

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How to get started

1. Install a suitable frame grabber in your PC.

   To find a compliant frame grabber, please see the frame grabber compatibility list at www.photonfocus.com.

   For US and Canada: Ensure the device downstream of the camera data path (e.g. frame grabber, PC) is UL listed.

2. Install the frame grabber software.

   Without installed frame grabber software the camera configuration tool PFRemote will not be able to communicate with the camera. Please follow the instructions of the frame grabber supplier.

3. Remove the camera from its packaging. Please make sure the following items are included with your camera:
   - Power supply connector (7-pole power plug)
   - Camera body cap

   If any items are missing or damaged, please contact your dealership.
4. Remove the camera body cap from the camera and mount a suitable lens.

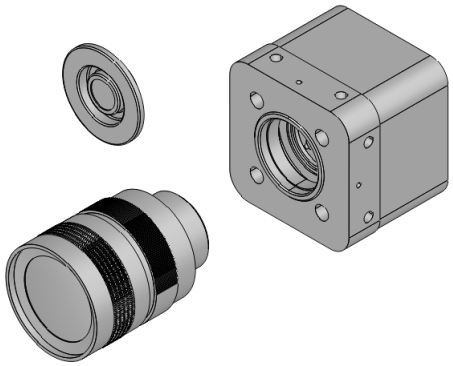

Figure 2.1: Camera with protective cap and lens.

Do not touch the sensor surface. Protect the image sensor from particles and dirt!

To choose a lens, see the Lens Finder in the 'Support' area at www.photonfocus.com.

5. Connect the camera to the frame grabber with a suitable CameraLink cable (see Fig. 2.2).

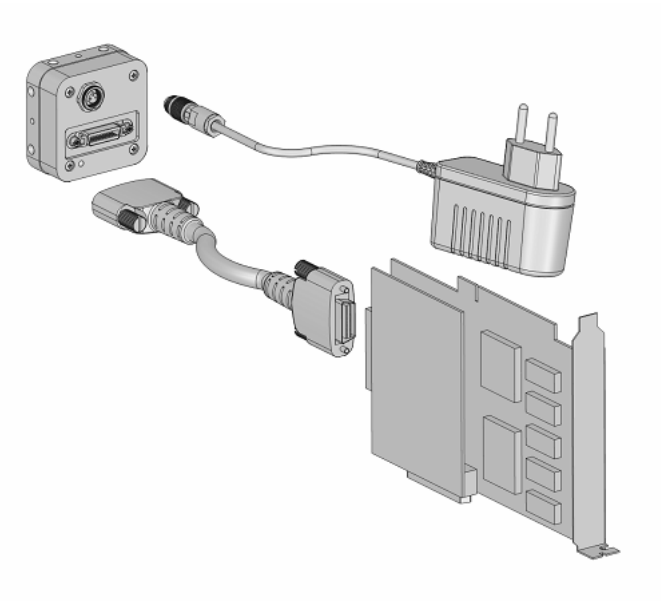

Figure 2.2: Camera with frame grabber, power supply and cable.

Do not connect or disconnect the CameraLink cable while camera power is on! For more information about CameraLink see Section 4.8.

6. Connect a suitable power supply to the provided 7-pole power plug. For the connector assembly see Fig. A.1.

Check the correct supply voltage and polarity! Do not exceed the maximum operating voltage of +12V DC (± 10%).

The pinout of the connector is shown in Section A.1.

For US and Canada: Ensure a UL listed power supply is used. A suitable UL listed power supply is available from Photonfocus.

7. Connect the power supply to the camera (see Fig. 2.2).

The status LED on the rear of the camera will light red for a short moment, and then flash green. For more information see Section 5.1.4.

8. Download the camera software PFRemote to your computer.

You can find the latest version of PFRemote on the support page at www.photonfocus.com.

9. Install the camera software PFRemote. Please follow the instructions of the PFRemote setup wizard.

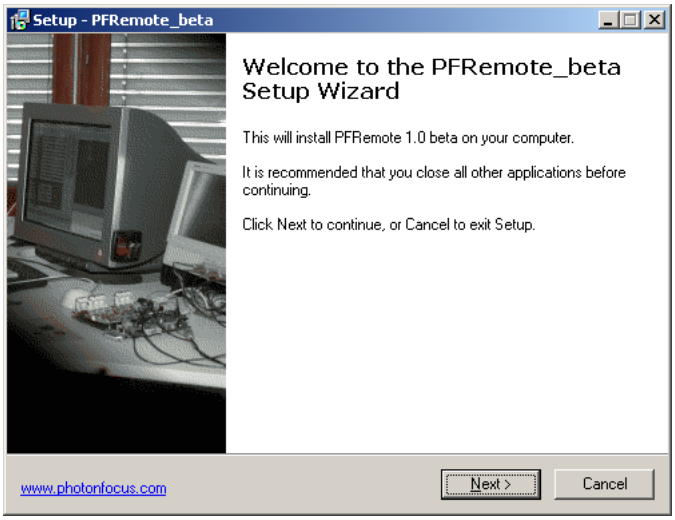
Setup - PFRemote_beta
Welcome to the PFRemote_beta Setup Wizard
This will install PFRemote 1.0 beta on your computer.
It is recommended that you close all other applications before continuing.
Click Next to continue, or Cancel to exit Setup.
www.photonfocus.com
Next >
Cancel

Figure 2.3: Screen shot PFremote setup wizard

10. Start the camera software PFRemote and choose the communication port.

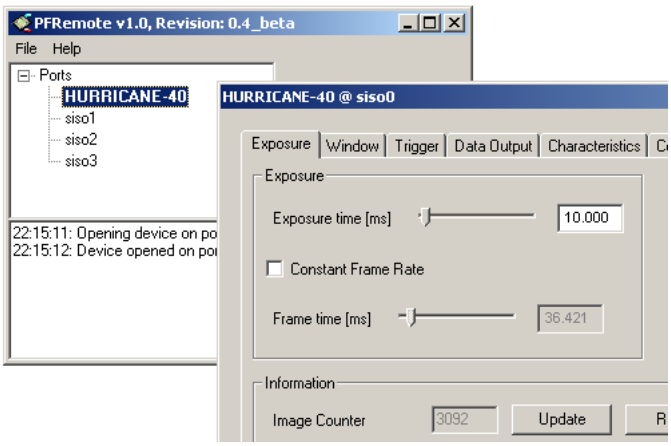

Figure 2.4: PFRemote start windows

11. Check the status LED on the rear of the camera.

The status LED lights green when an image is being produced, and it is red when serial communication is active. For more information see Section 5.1.4.

12. You may display images using the software that is provided by the frame grabber manufacturer.

3

Product Specification

3.1 Introduction

The HURRICANE CMOS camera from Photonfocus is aimed at demanding applications in industrial image processing. It provides an exceptionally high dynamic range of up to 120dB at a resolution of 1024 x 1024 pixels. The cameras are built around a monochrome CMOS image sensor, developed by Photonfocus. The principal advantages are:

- Low power consumption at high speeds
- Resistance to blooming
- Extremely high image contrast achieved by LinLog technology.
- Ideal for high speed applications: global shutter, in combination with several simultaneously selectable read out windows (Multiple ROI).
- Gray level resolution up to 12 bit
- Software is provided to set camera parameters and store them within the camera.
- The cameras have a digital CameraLink interface.
- The compact size of only 55 x 55 x 39 mm^3 makes the HURRICANE series the perfect solution for applications in which space is at a premium.

The general specification and features of the camera are listed in the following sections.

3.2 Feature Overview

	HURRICANE CameraLink Series
Interfaces	CameraLink base configuration
Camera Control	PFRemote (Windows GUI) or programming library (Windows)
Configuration Interface	CLSERIAL (9'600 baud)
Trigger Modes	Interface Trigger / I/O Trigger
Exposure Time	Defined by camera or trigger pulse width
Features	Linear Mode / LinLog Mode / Skimming
	Shading Correction (Offset and Gain)
	Gray level resolution 12 bit / 10 bit / 8 bit
	Region of Interest (ROI) / Multiple Regions of Interest (MROI)
	Look-up table (10 to 8 bit) / Decimation
	Trigger input / Strobe output with programmable delay
	Test pattern / Image information / Status line

Table 3.1: Feature overview (see Chapter 4 for more information)

3.3 Technical Specification

	HURRICANE Series
Technology	CMOS active pixel
Scanning system	progressive scan
Optical format / diagonal	1” / 15.42mm
Resolution	1024 x 1024 pixels
Pixel size	10.6μm x 10.6μm
Active optical area	10.9mm x 10.9mm
Random noise	< 0.5 DN RMS @ 8 bit / gain= 1
Fixed pattern noise (FPN)	< 1 DN RMS @ 8 bit / gain= 1 / offset correction on
Dark current	2fA/pixel @ 30°C
Full well capacity	200ke$^-$
Spectral range	400nm ... 900nm
Responsivity	120x10^3 DN/(J/m^2) @ 610nm / 8 bit / gain = 1
Optical fill factor	35%
Dynamic range	> 120dB (with LinLog)
Color format	monochrome
Characteristic curve	linear or LinLog, skimming
Shutter mode	global shutter
Readout mode	sequential integration and readout
Min. Region of Interest (ROI)	1 row x 9 columns
Grayscale Resolution	12 bit / 10 bit / 8 bit
Digital Gain	x1 / x2 / x4
Exposure Time	10 μs ... 0.41 s

Table 3.2: General specification of the HURRICANE series

	HURRICANE-40
Exposure Time Increment	25 ns
Frame Rate (T_{int} = 10 μs)	37 fps
Pixel Clock Frequency	40 MHz
Pixel Clock Cycle	25 ns
Camera Taps	1

Table 3.3: Model-specific parameters

	HURRICANE-40
Operating temperature	0°C ... 60°C
Camera power supply	+12V DC (±10%)
Trigger signal input range	+5 .. +15V DC
Strobe signal power supply	+5 .. +15V DC
Strobe signal sink current (average)	max. 8mA
Max. power consumption	1.6 W
Lens mount	C- or CS-Mount
Dimensions	55 x 55 x 39 mm^3
Mass	200 g
Conformity	CE / UL

Table 3.4: Physical characteristics and operating ranges

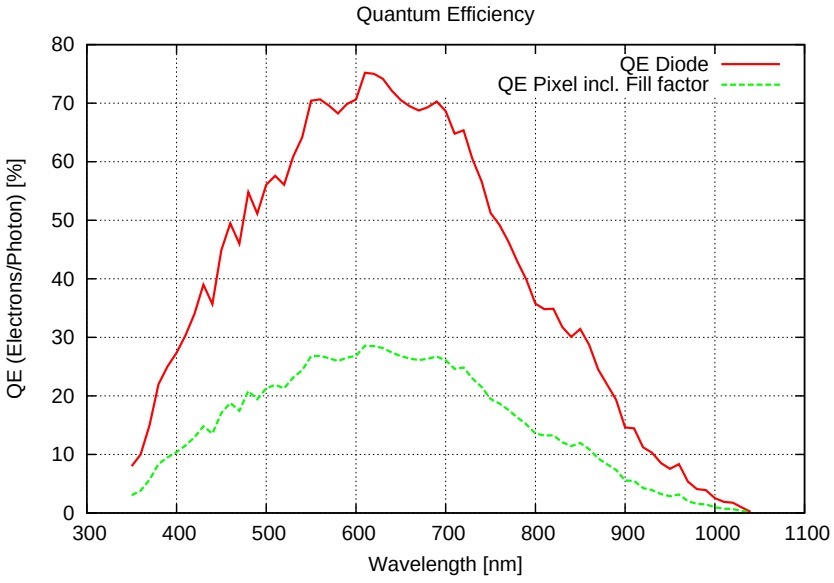

Figure 3.1: Spectral response

3.4 Frame Grabber relevant Configuration

	HURRICANE-40
Pixel Clock per Tap	40 MHz
Number of Taps	1
Grayscale resolution	12 bit / 10 bit / 8 bit
CC1	EXSYNC
CC2	not used
CC3	not used
CC4	not used

Table 3.5: Summary of parameters needed for frame grabber configuration

CameraLink Port and Bit assignments are compliant to the CameraLink standard (see [CL]).

Bit	Tap 0, 8 Bit	Tap 0, 10 Bit	Tap 0, 12 Bit
0 (LSB)	A0	A0	A0
1	A1	A1	A1
2	A2	A2	A2
3	A3	A3	A3
4	A4	A4	A4
5	A5	A5	A5
6	A6	A6	A6
7 (MSB for 8 Bit Mode)	A7	A7	A7
8	-	B0	B0
9 (MSB for 10 Bit Mode)	-	B1	B1
10	-	-	B2
11 (MSB for 12 Bit Mode)	-	-	B4

Table 3.6: CameraLink port and bit assignments for Hurricane series

4

Functionality

This chapter serves as an overview of the camera configuration modes and explains camera features. The goal is to describe what can be done with the camera; the setup is explained in later chapters.

4.1 Image Acquisition

4.1.1 Free-running and Trigger Mode

By default the camera continuously delivers images ("Free-running mode").

Figure 4.1: Timing in free-running mode

When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used (refer to Section 4.6 and Section 5.4). In this mode, the camera is idle until it gets a signal to capture an image.

Figure 4.2: Timing in any triggered mode

4.1.2 Exposure Control

The exposure time defines the period during which the image sensor integrates the incoming light. Refer to Table 3.3 for the allowed exposure time range and see Section 5.4.1

4.1.3 Maximum Frame Rate

The maximum frame rate depends on the exposure time and the size of the image (see Region of Interest, Section 4.5.1).

4.1.4 Constant Frame Rate (CFR)

When the CFR mode is switched on, the frame rate (number of frames per second) can be varied from almost 0 up to the maximum frame rate. Thus, fewer images can be acquired than would otherwise be possible.
When Constant Frame Rate is switched off, the camera delivers images as fast as possible, depending on the exposure time and the read-out time. See Section 5.3.2 for more information.

Constant Frame Rate mode (CFR mode) is not available together with external trigger mode.

4.2 Image Information

There are camera properties available that give information about the acquired images, such as an image counter, average image value and the number of missed trigger signals. These properties can be queried by software. Alternatively, a status line within the image data can be switched on that contains all the available image information properties.

4.2.1 Counters and Average Value

Image counter The image counter provides a sequential number of every image that is output. After camera startup, the counter counts up from 0 (counter width 24 bit). The counter can be reset by the software.

Missed trigger counter The missed trigger counter counts trigger pulses that were ignored by the camera because they occurred within the exposure or read-out time of an image. In free-running mode it counts all incoming external triggers. (Counter width 8 bit / no wrap around).

Average image value The average image value gives the average of an image in 12 bit format (0 .. 4095 DN), regardless of the currently used gray level resolution.

4.2.2 Status Line

If enabled, the status line replaces the last row of the image with image information. It contains the properties described above and additional information:

Preamble The first parameter contains a constant value of 0x55AA00FF as a preamble in order to recognise the status line easily by the image processing system.

Image counter See Section 4.2.1.

Time counter The time counter starts at 0 after camera start, and counts real-time in units of 1 micro-second. The time counter can be reset by the software in the SDK (Counter width 32 bit).

Missed trigger counter See Section 4.2.1.

Average image value See Section 4.2.1.

Exposure cycles The exposure cycles parameter outputs the current exposure time in units of clock cycles (see Table 3.3).

Every parameter is coded into 4 pixels (LSB first) and uses the lower 8 bits of the pixel value, so that the total size of a parameter is 32 bit. The remaining pixels (24..1024) are set to 0.

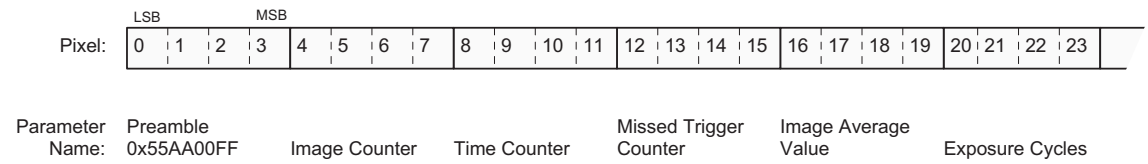

Figure 4.3: Status line parameters replace the last row of the image

The status line is also available when using an ROI. For an ROI with a width <24 pixels, the status line will be clipped.

4.3 Pixel Response

4.3.1 Linear Response

Normally, the camera offers a substantially linear response between input light signal and output gray level. This can be modified by the use of LinLog or Skimming as described in the following sections. In addition, a linear digital gain may be applied, as follows. Please see Table 3.2 for more model-dependent information.

Gain x1, x2, x4

Gain x1, x2 and x4 are digital amplifications, which means that the digital image data are multiplied by a factor 1, 2 or 4 respectively, in the camera.

Black Level Adjustment

The black level is the average image value at no intensity. It can be adjusted by the software by changing the black level offset. Thus, the overall image gets brighter or darker.

4.3.2 LinLog

Overview

The LinLog technology from Photonfocus allows a logarithmic compression of high light intensities. In contrast to the classical non-integrating logarithmic pixel, the LinLog pixel is an integrating pixel with global shutter and the possibility to control the transition between linear and logarithmic mode.
In situations involving high intrascene contrast, a compression of the upper gray level region can be achieved with the LinLog technology. At low intensities, each pixel shows a linear response. At high intensities, the response changes to logarithmic compression (see Fig. 4.4). The transition region between linear and logarithmic response can be smoothly adjusted by software and is continuously differentiable and monotonic.

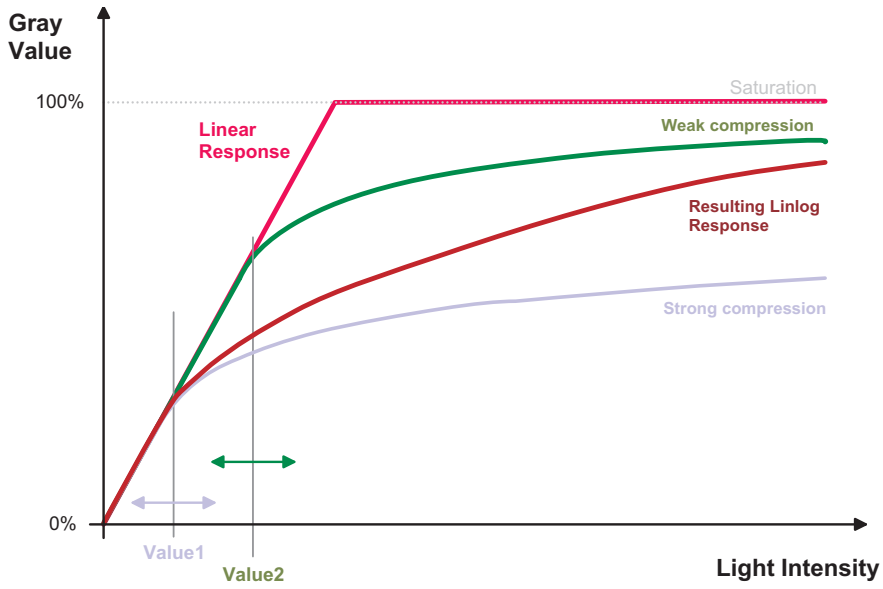

Figure 4.4: Resulting LinLog2 response curve

LinLog is controlled by up to 4 parameters (`Time1`, `Time2`, `Value1` and `Value2`). `Value1` and `Value2` correspond to the LinLog voltage that is applied to the sensor. The higher the parameters `Value1` and `Value2` respectively, the stronger the compression for the high light intensities. `Time1` and `Time2` are normalised to the exposure time. They can be set to a maximum value of 1000, which corresponds to the exposure time.
Examples in the following sections illustrate the LinLog feature.

LinLog1

In the simplest way the pixels are operated with a constant LinLog voltage which defines the knee point of the transition.This procedure has the drawback that the linear response curve goes directly to a logarithmic curve leading to a poor gray resolution in the logarithmic region (see Fig. 4.6).

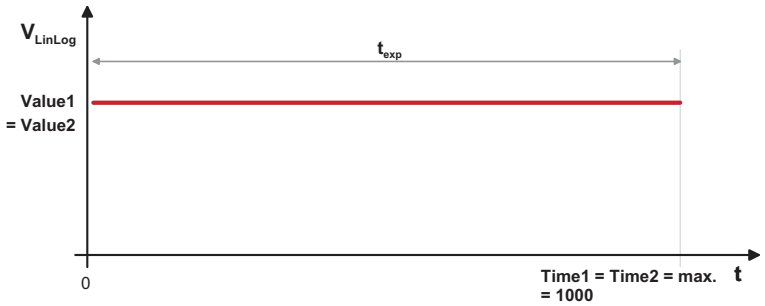

Figure 4.5: Constant LinLog voltage in the Linlog1 mode

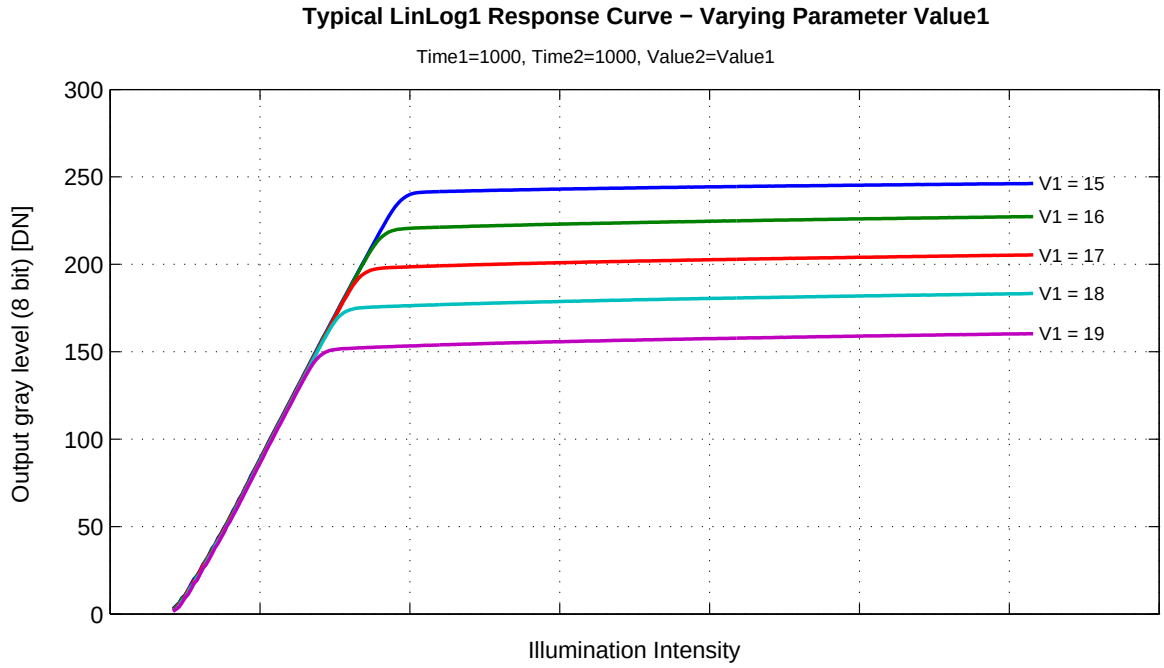

Figure 4.6: Response curve for different LinLog settings in LinLog1 mode

LinLog2

To get more gray resolution in the LinLog mode, the LinLog2 procedure was developed. In LinLog2 mode a switching between two different logarithmic compressions occurs during the exposure time (see Fig. 4.7). The exposure starts with strong compression with a high LinLog voltage (`Value1`). At `Time1` the LinLog voltage is switched to a lower voltage resulting in a weaker compression. This procedure gives a LinLog response curve with more gray resolution. Fig. 4.8 and Fig. 4.9 show how the response curve is controlled by the three parameters `Value1`, `Value2` and the LinLog time `Time1`.

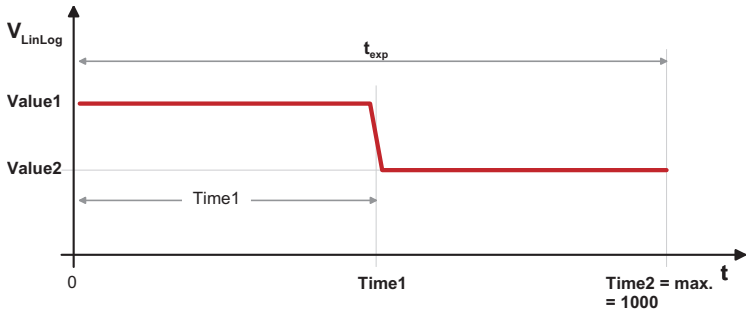

Figure 4.7: Voltage switching in the Linlog2 mode

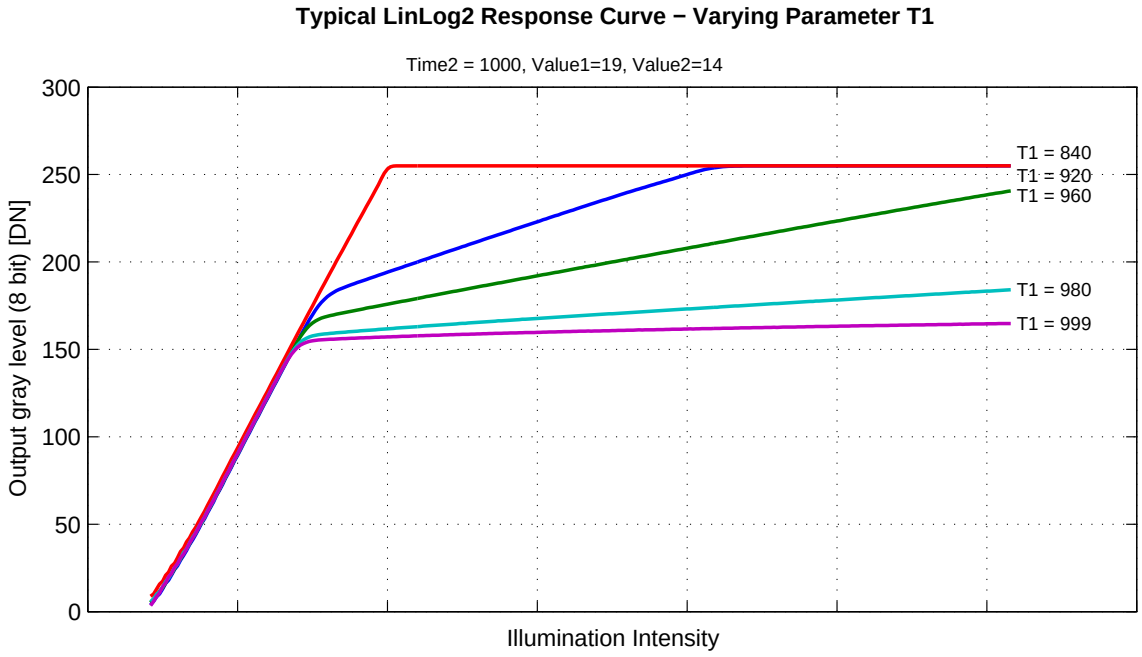

Figure 4.8: Response curve for different LinLog settings in LinLog2 mode

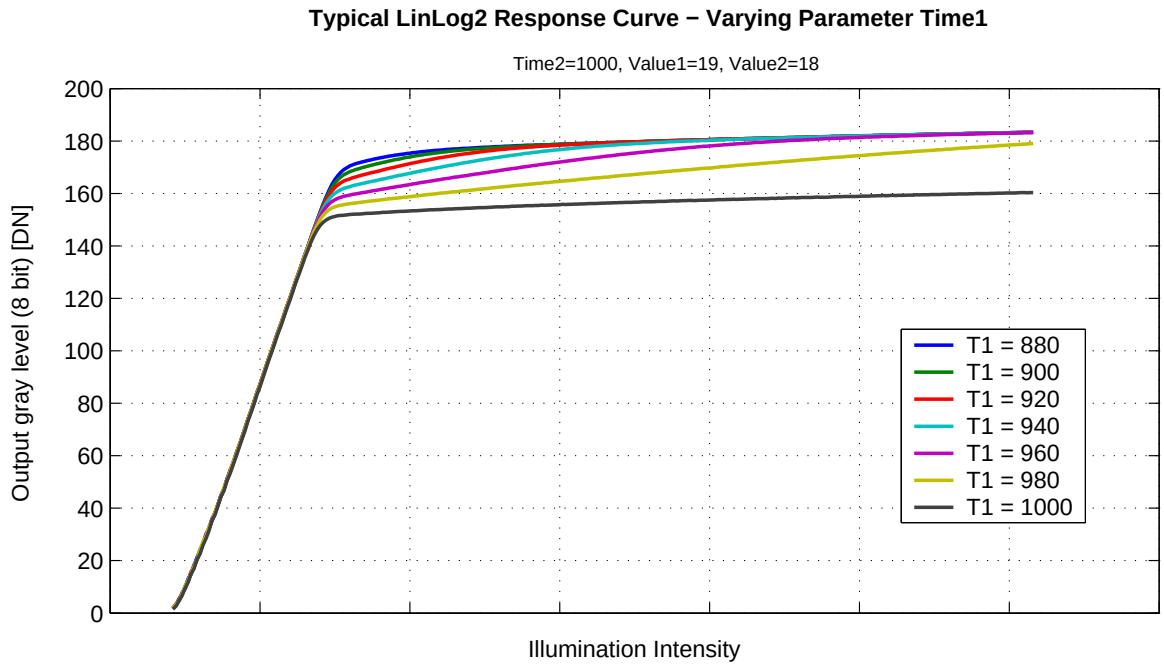

Figure 4.9: Response curve for different LinLog settings in LinLog2 mode

LinLog3

To enable more flexibility the LinLog3 mode with 4 parameters was introduced. Fig. 4.10 shows the timing diagram for the LinLog3 mode and the control parameters.

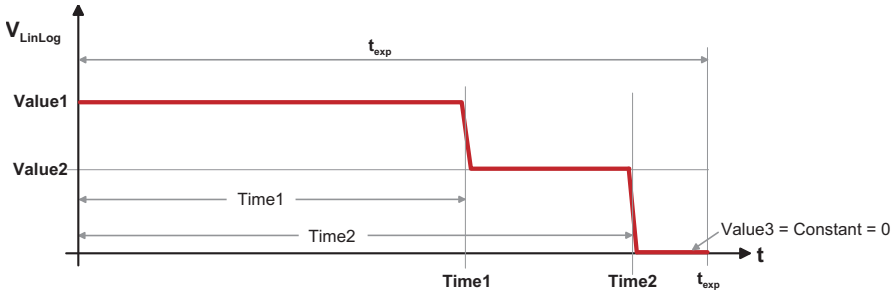

Figure 4.10: Voltage switching in the Linlog3 mode

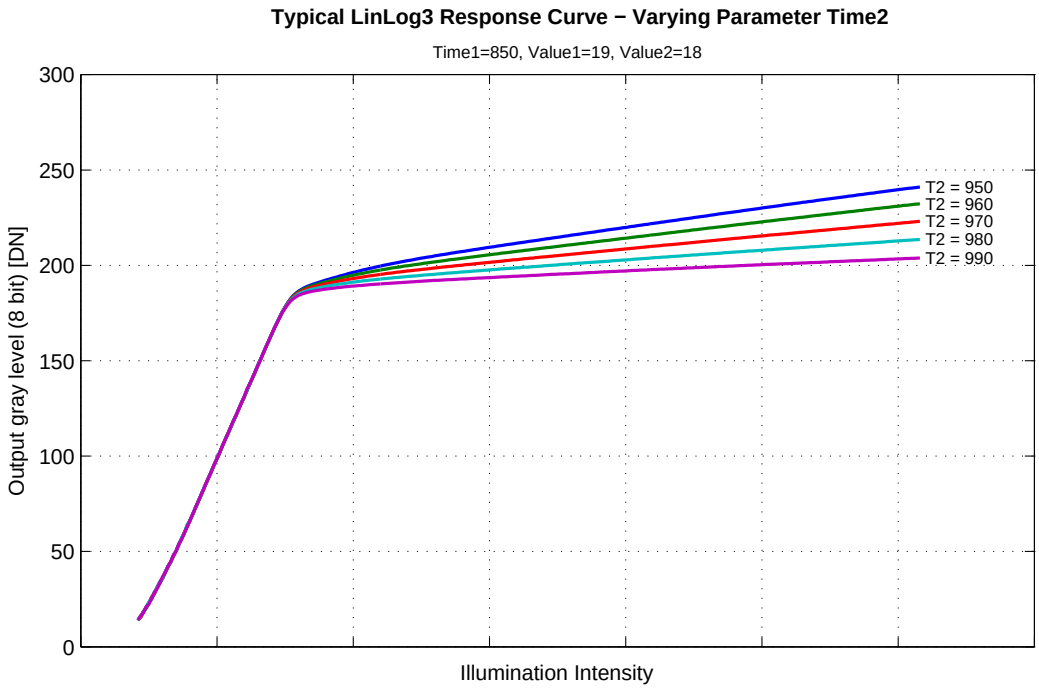

Figure 4.11: Response curve for different LinLog settings in LinLog3 mode

4.3.3 Skimming

Skimming is a Photonfocus proprietary technology to enhance detail in dark areas of an image. Skimming provides an adjustable level of in-pixel gain for low signal levels. It can be used together with LinLog to give a smooth monotonic transfer function from high gain at low levels, through normal linear operation, to logarithmic compression for high signal levels (see Fig. 4.12). The resulting response is similar to a gamma correction.

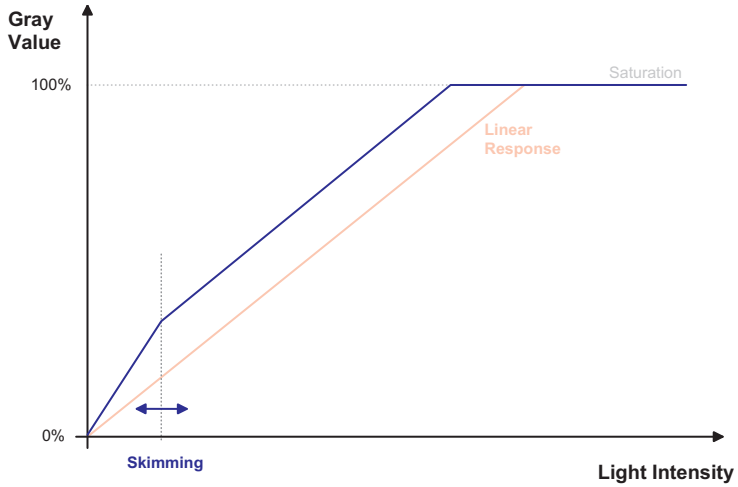

Figure 4.12: Response Curve for different skim settings

4.3.4 Gray Level Transformation (LUT)

Gray level transformation is remapping of the gray level values of an input image to new values. The look-up table (LUT) is used to convert the grayscale value of each pixel in an image into another gray value. It is typically used to implement a transfer curve for contrast expansion. The camera performs a 10-to-8-bit mapping, so that 1024 input gray levels can be mapped to 256 output gray levels. The use of the three available modes is explained in the next sections.

The output gray level resolution of the look-up table (independent of gain, gamma or user-definded mode) is always 8 bit.

Gain

The 'Gain' mode performs a digital, linear amplification (see Fig. 4.13). It is configurable in the range from 1.0 to 4.0. (e.g. 1.234)

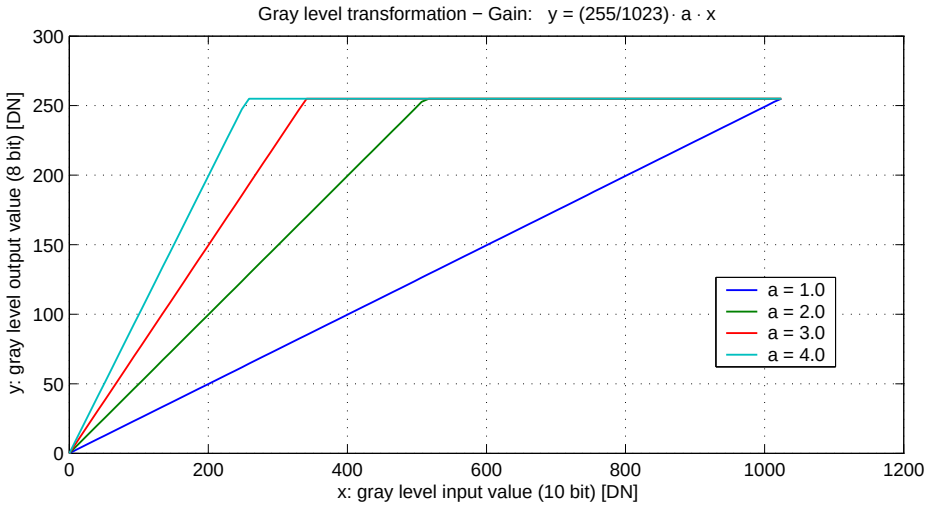

Figure 4.13: Applying a linear gain to the image

Gamma

The 'Gamma' mode performs an exponential amplification, configurable in the range from 0.4 to 4.0. gamma > 1.0 results in an attenuation of the image (see Fig. 4.14), gamma < 1.0 results in an amplification (see Fig. 4.15).

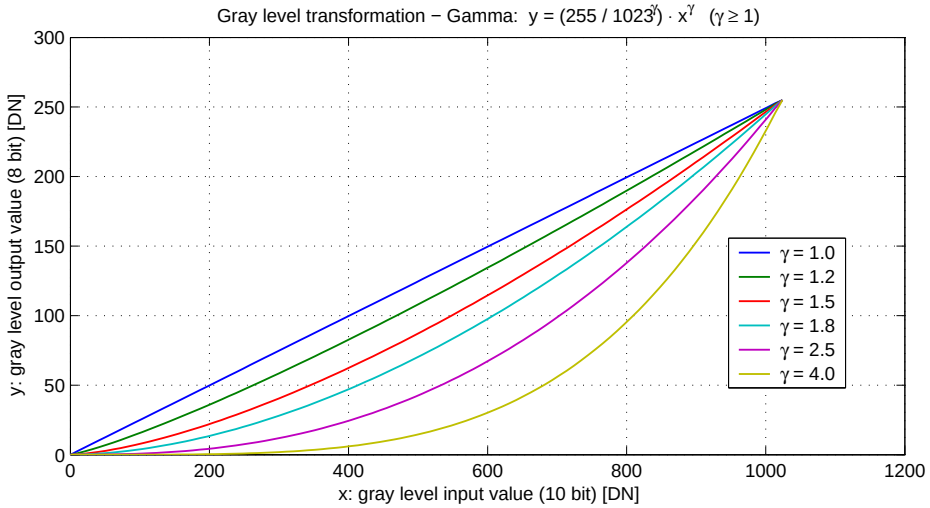
Gray level transformation − Gamma: y = (255 / 1023^γ) · x^γ (γ ≥ 1)
y: gray level output value (8 bit) [DN]
x: gray level input value (10 bit) [DN]
γ = 1.0
γ = 1.2
γ = 1.5
γ = 1.8
γ = 2.5
γ = 4.0

Figure 4.14: Applying gamma correction to the image

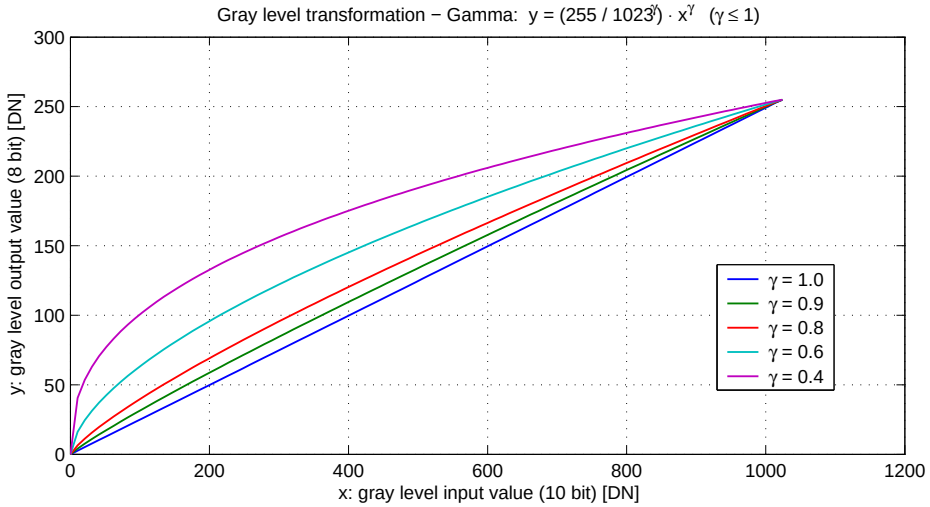
Gray level transformation − Gamma: y = (255 / 1023^γ) · x^γ (γ ≤ 1)
y: gray level output value (8 bit) [DN]
x: gray level input value (10 bit) [DN]
γ = 1.0
γ = 0.9
γ = 0.8
γ = 0.6
γ = 0.4

Figure 4.15: Applying gamma correction to the image

User-defined Look-up Table

In the 'User' mode, the mapping of input to output gray levels can be configured arbitrarily by the user. See Section 6.4.4 for more information.

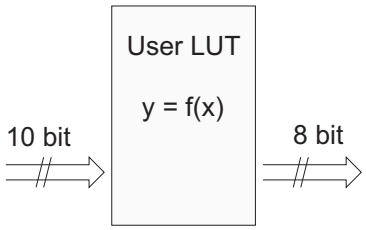

Figure 4.16: Applying gamma correction to the image

4.3.5 Test Images

Test images are generated in the camera FPGA, independent of the image sensor. They can be used to check the transmission path from the camera to the frame grabber. Independent from the configured gray level resolution, every possible gray level appears the same number of times in a test image. Therefore, the histogram of the received image must be flat.

A test image is a useful tool to find data transmission errors that are caused most often by a defective cable between camera and frame grabber.

Test images give the correct result at full resolution only.

Ramp

Depending on the configured gray level resolution, the ramp test image outputs a constant pattern with increasing gray level from the left to the right side (see Fig. 4.17).

Figure 4.17: Ramp test images: 8 bit output (left), 10 bit output (middle), 12 bit output (right)

LFSR

The LFSR (linear feedback shift register) test image outputs a constant pattern with a pseudo-random gray level sequence containing every possible gray level that is repeated for every row. In 12 bit mode only a fourth of all possible gray values appear.

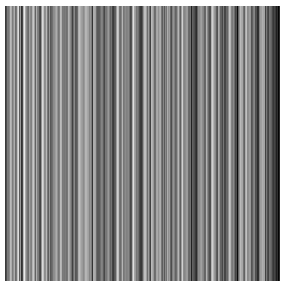

Figure 4.18: LFSR test image

In the histogram you can see that the number of pixels of all gray values are the same. Please refer to application note [AN026] for the calculation and the values of the LFSR test image.

4.4 Image Correction

4.4.1 Overview

The HURRICANE and THUNDER camera series possess image pre-processing features, that compensate for non-uniformities caused by the sensor, the lens or the illumination. This method of improving the image quality is generally known as 'Shading Correction' or 'Flat Field Correction' and consists of a combination of offset correction, gain correction and pixel interpolation.

Since the correction is performed in hardware, there is no performance limitation for high frame rates.

The offset correction subtracts a configurable positive or negative value from the live image and thus reduces the fixed pattern noise of the CMOS sensor. In addition, hot pixels can be removed by interpolation. The gain correction can be used to flatten uneven illumination or to compensate shading effects of a lens. Both offset and gain correction work on a pixel-per-pixel basis, i.e. every pixel is corrected separately. For the correction, a black reference and a gray reference image are required. Then, the correction values are determined automatically in the camera.

Do not set any reference images when gain or LUT is enabled.

Correction values of both reference images can be saved into the internal flash memory, but this overwrites the factory presets. The reference images that are delivered by factory cannot be restored with the factory reset.

4.4.2 Offset Correction (FPN, Hot Pixels)

The offset correction is based on a black reference image, which is taken at no illumination (e.g. lens aperture completely closed). The black reference image contains the fixed-pattern noise of the sensor, which can be subtracted from the live images in order to minimise the static noise.

Offset correction algorithm

After configuring the camera with a black reference image, the camera is ready to apply the offset correction:

1. Determine the average value of the black reference image.
2. Subtract the black reference image from the average value.
3. Mark pixels that have a gray level bigger than 1008 DN (@ 12 bit) as hot pixels.
4. Store the result in the camera as the offset correction matrix.
5. During image acquisition, subtract the correction matrix from the acquired image and interpolate the hot pixels (see Section 4.4.2).

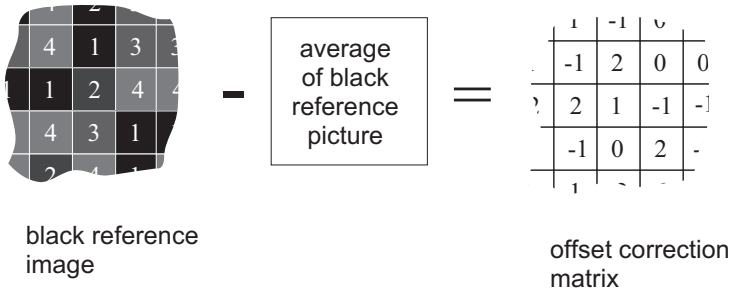

Figure 4.19: Offset correction

How to Obtain a Black Reference Image

In order to improve the image quality, the black reference image must meet certain demands.

- The black reference image must be obtained at no illumination, e.g. with lens aperture closed or closed lens opening.
- It may be necessary to adjust the black level offset of the camera. In histogram of the black reference image, ideally there are no gray levels at value 0 DN after adjustment of the black level offset. All pixels that are saturated black (0 DN) will not be properly corrected (see Fig. 4.20). The peak in the histogram should be well below the hotpixel threshold of 1008 DN @ 12 bit.
- Camera settings such as exposure time, LinLog, skimming and digital gain may influence the gray level. Therefore, for best results the camera settings of the black reference image must be identical with the camera settings of the corrected image.

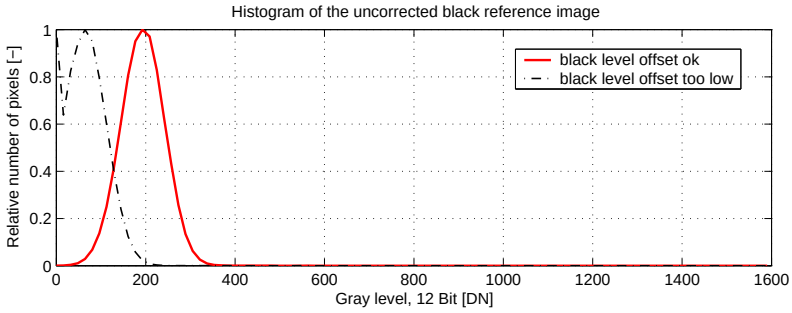

Figure 4.20: Histogram of a proper black reference image for offset correction

Hot pixel correction

Every pixel that exceeds a certain threshold in the black reference image is marked as a hot pixel. If the hot pixel correction is switched on, the camera replaces the value of a hot pixel by an average of its neighbour pixels (see Fig. 4.21).

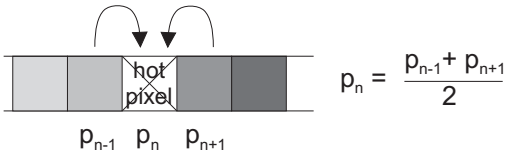

Figure 4.21: Hot pixel interpolation

4.4.3 Gain Correction

The gain correction is based on a gray reference image, which is taken at uniform illumination to give an image with a mid gray level.

Gain correction is not a trivial feature. The quality of the gray reference image is crucial for proper gain correction.

Gain correction algorithm

After configuring the camera with a black and gray reference image, the camera is ready to apply the gain correction:

1. Determine the average value of the gray reference image.
2. Subtract the offset correction matrix from the gray reference image.
3. Divide the average value by the offset corrected gray reference image.
4. Pixels that have a gray level bigger than a certain threshold are marked as hot pixels.
5. Store the result in the camera as the gain correction matrix.
6. During image acquisition, multiply the gain correction matrix from the offset-corrected acquired image and interpolate the hot pixels (see Section 4.4.2).

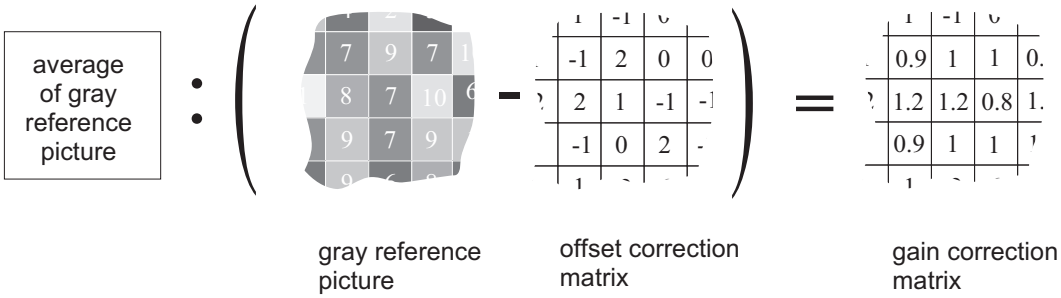

Figure 4.22: Gain Correction

Gain correction needs always an offset correction matrix, so the offset correction has to be performed before the gain correction.

How to Obtain a Gray Reference Image

In order to improve the image quality, the gray reference image must meet certain demands.

- The gray reference image must be obtained at uniform illumination.

  Use a high quality light source that delivers uniform illumination. Standard illumination will not be appropriate.

- When looking at the histogram of the gray reference image, ideally there are no gray levels at full scale (4095 DN @ 12 bit). All pixels that are saturated white will not be properly corrected (see Fig. 4.23).
- Camera settings such as exposure time, LinLog, skimming and digital gain may influence the gray level. Therefore, the camera settings of the gray reference image must be identical with the camera settings of the corrected image.

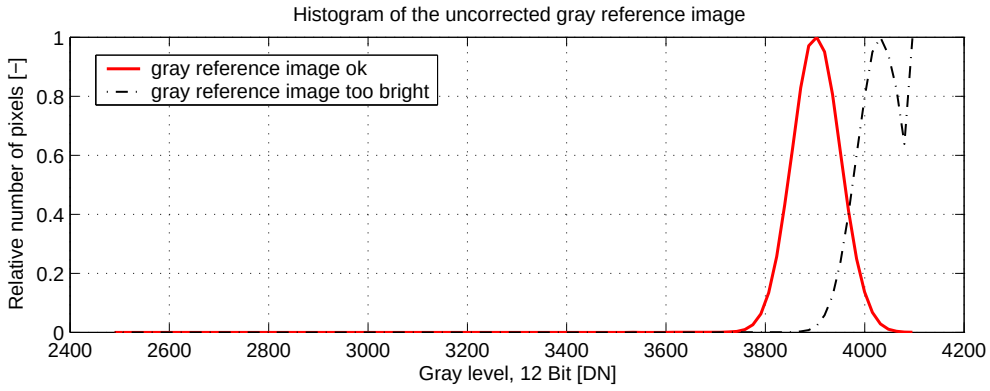

Figure 4.23: Proper gray reference image for gain correction

4.4.4 Corrected Image

Offset, gain and hot pixel correction can be switched on seperately. The following configuration is possible:

- No correction
- Offset correction only
- Offset and hot pixel correction
- Hot pixel correction only
- Offset and gain correction
- Offset, gain and hot pixel correction

In addition, the black reference image and gray reference image that are currently stored in the camera RAM can be output.
Table 4.1 shows the maximum values of the correction matrices, i.e. the error range that the offset and gain algorithm can correct.

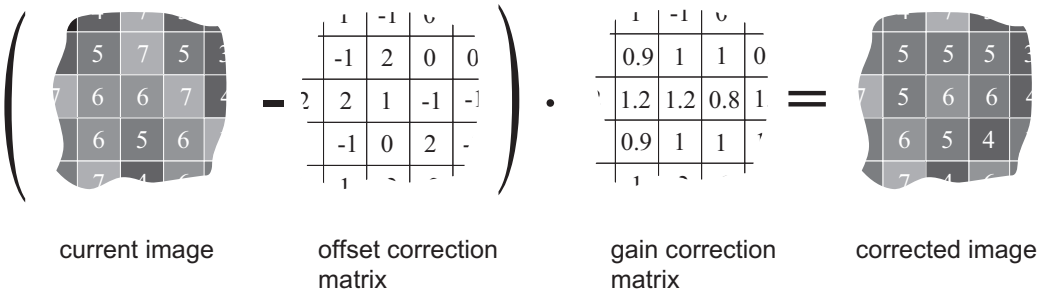

Figure 4.24: Corrected image

	minimum	maximum
Offset correction	-508 DN @ 12 bit	+508 DN @ 12 bit
Gain correction	0.42	2.67

Table 4.1: Offset and gain correction ranges

4.5 Reduction of Image Size

With Photonfocus cameras there are several possibilities to focus on the interesting parts of an image, thus reducing the data rate and increasing the frame rate. The most commonly used feature is Region of Interest.

4.5.1 Region of Interest

Some applications do not need full image resolution (e.g. 1024x1024 pixels). By reducing the image size to a certain region of interest (ROI), the frame rate can be drastically increased. A region of interest can be almost any rectangular window and is specified by its position within the full frame and its width and height. Fig. 4.25 gives some possible configurations for a region of interest, and Table 4.2 shows some numerical examples of how the frame rate can be increased by reducing the ROI.

Both reductions in x- and y-direction result in a higher frame rate.

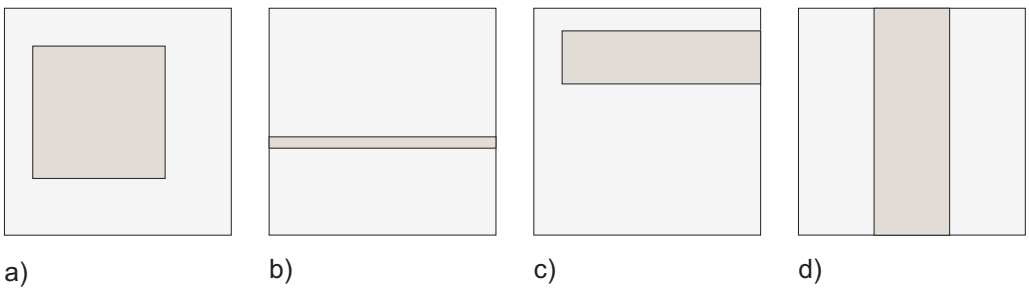

Figure 4.25: ROI configuration examples

ROI Dimension	HURRICANE-40
1024 x 1024	37 fps
512 x 512	149 fps
256 x 256	586 fps
128 x 128	2230 fps
128 x 16	14 789 fps
1024 x 1	25 940 fps

Table 4.2: Example: Frame rate increase for the HURRICANE when using a reduced region of interest (exposure time 10 μs; correction, LUT and skimming off)

Calculation of the maximum frame rate

The frame rate depends on the exposure time, frame pause, ROI and image correction.

Frame time = (1 / frame rate)
Frame time = exposure time + read out time + processing time + RAM refresh time
Read out time = t_U * (P_y * (P_x + LP) + LP + CPRE)
Processing time = t_{Normal} + t_{LUT} + t_{FPN} + t_{Skim}
RAM refresh time = $\frac{1}{128}$ * (read out time + 1375 μs) - (exposure time + processing time)

When the result of the above equation is negative, set RAM refresh time to 0.

	$\mathbf{t_{Int}}$	exposure time (10 μs . . . 0.41 s)
	$\mathbf{t_{Normal}}$	1125 ns latency
	$\mathbf{t_{LUT}}$	50 ns (only when LUT enabled)
	$\mathbf{t_{FPN}}$	425 ns (only when correction enabled)
	$\mathbf{t_{Skim}}$	2048 clock cycles (51.2 μs) (only when Skim enabled)
hspace*-0.32cm	$\mathbf{t_U}$	pixel clock in ns (refer to Table 3.3)
	$\mathbf{P_X}$	number of pixels in x-direction (9 . . . 1024 columns)
	$\mathbf{P_Y}$	number of pixels in y-direction (1 . . . 1024 rows)
	LP	constant line pause = 8 cycles for all models
	CPRE	clocks between completed integration and begin of data transfer (constant CPRE = 57 clock cycles)

A calculator for calculating the maximum frame rate is available in the support area of the Photonfocus website.

4.5.2 Multiple Regions of Interest

The HURRICANE and THUNDER cameras can handle up to 16 different regions of interest. This feature can be used to reduce the image data and increase the frame rate. An application example for using multiple regions of interest (MROI) is a laser triangulation system with several laser lines. The multiple ROIs are joined together and form a single image, which is transferred to the frame grabber.
An ROI is defined by its starting value in y-direction and its height. Every ROI within a MROI must be of the same width. The maximum frame rate in MROI mode depends on the number of rows and columns being read out. Overlapping ROIs are allowed. See Section 4.5.1 for information on the calculation of the maximum frame rate.

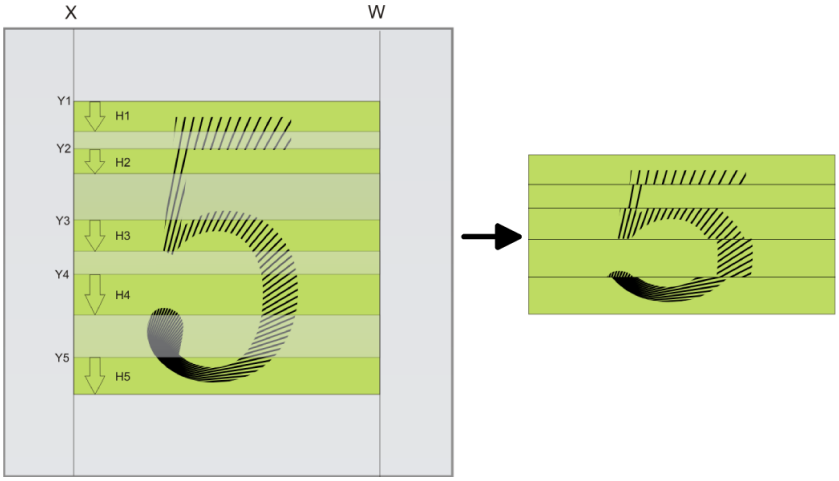

Figure 4.26: Example: Multiple Regions of Interest with 5 ROIs

4.5.3 Decimation

Decimation reduces the number of pixels in x- and y-direction. Decimation can also be used together with ROI or MROI. Decimation in y-direction transfers every n^{th} row only and directly results in reduced read-out time and higher frame rate respectively. Decimation in x-direction transfers every pixel of a row, but uses the CameraLink DVAL (data valid) signal to indicate which pixels to mask (see 4.27). Therefore it cannot be used to increase the frame rate.

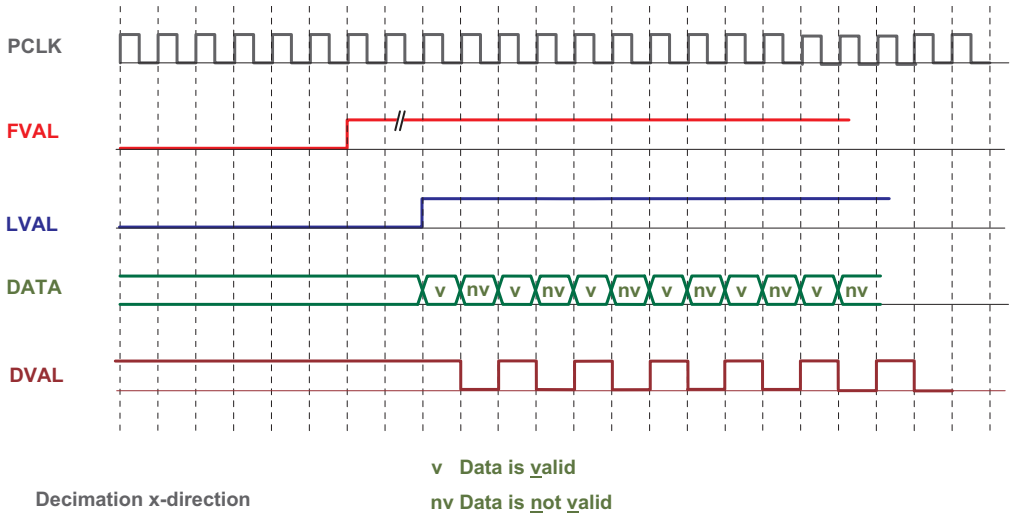

Figure 4.27: Decimation in x-direction uses the CameraLink DVAL signal

Please consult the documentation of your frame grabber on how to configure the frame grabber such that it interprets the DVAL signal.

4.6 External Trigger

An external trigger is an event that starts an exposure. The trigger signal is either generated on the frame grabber (soft-trigger) or comes from an external device such as a light barrier. If a trigger signal is applied to the camera during the exposure or read-out time, the trigger will be ignored. The camera property `missed trigger counter` stores the number of trigger events which where ignored.

4.6.1 Trigger Source

The trigger signal can be configured to be active high or active low. One of the following trigger sources can be used:

Interface Trigger In the interface trigger mode, the trigger signal is applied to the camera by the CameraLink frame grabber or the USB interface (if available) respectively.

I/O Trigger In the I/O trigger mode, the trigger signal is applied directly to the camera by the power supply connector.

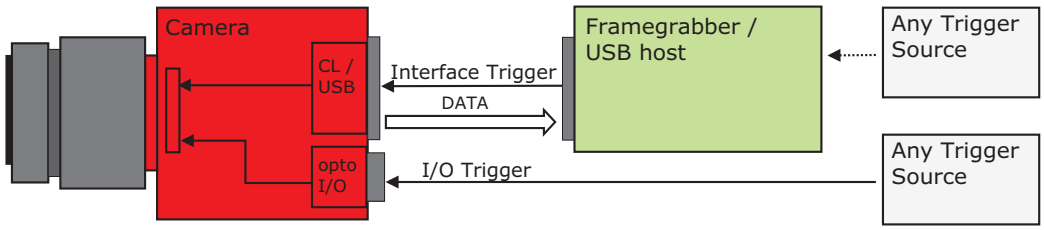

Figure 4.28: Trigger Inputs

4.6.2 Trigger Mode

Depending on the trigger mode, the exposure time can be determined either by the camera or by the trigger signal itself:

Camera-controlled Exposure In this trigger mode the exposure time is defined by the camera. For an active high trigger signal, the camera starts the exposure with a positive trigger edge and stops it when the preprogrammed exposure time has elapsed. The exposure time is defined by the software.

Level-controlled Exposure In this trigger mode the exposure time is defined by the pulse width of the trigger pulse. For an active high trigger signal, the camera starts the exposure with the positive edge of the trigger signal and stops it with the negative edge.

Figure 4.29 gives an overview over the available trigger modes. The signal ExSync stands for the trigger signal, which is provided either through the interface or the I/O trigger. For more

	Polarity Active High		Polarity Active Low	
	Exposure Start	**Exposure Stop**	**Exposure Start**	**Exposure Stop**
Camera controlled exposure	ExSync	Camera	ExSync	Camera
Level controlled exposure	ExSync	ExSync	ExSync	ExSync

Rising Edge
Falling Edge

Figure 4.29: Trigger Inputs

information and the respective timing diagrams see Section 5.4.

4.7 Strobe Output

The strobe output is an opto-isolated output located on the power supply connector that can be used to trigger a strobe. The strobe output can be used both in free-running and in trigger mode. There is a programmable delay available to adjust the strobe pulse to your application.

The strobe output needs a separate power supply. Please see Section 5.1.3 for more information.

4.8 Configuration Interface

A CameraLink camera can be controlled by the user via an RS232 compatible asynchronous serial interface. This interface is contained within the CameraLink interface as shown in Fig. 4.30 and is physically not directly accessible. Instead, the serial communication is usually routed through the frame grabber. For some frame grabbers it might be necessary to connect a serial cable from the frame grabber to the serial interface of the PC.

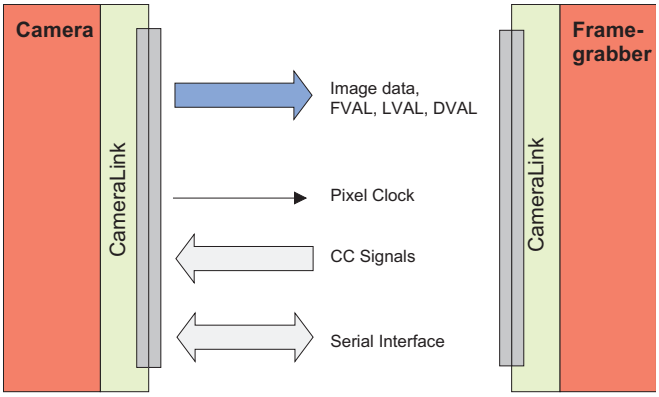

Figure 4.30: CameraLink serial interface for camera communication

To interface different cameras to different frame grabbers, the CameraLink standard defines a software API. It defines how the functions to initialise, read from, write to and close the serial interface should look. The code behind these functions is frame grabber specific and is written by the frame grabber manufacturer. The functions are then compiled into a DLL called `clserXXX.dll`, where `XXX` is a unique identifier for the frame grabber manufacturer.
The PFRemote camera configuration tool as well as the PFLib API use the serial interface to communicate with the camera and to control its functions. The serial interface is accessed via the `clserXXX.dll`. Therefore, the appropriate `clserXXX.dll` for the frame grabber manufacturer needs to be in the same directory as the PFRemote executable (e.g. `C:\Program Files\Photonfocus\PFRemote`). This DLL is usually located in the `windows\system32` directory after installing the frame grabber driver.
The serial configuration parameters are defined in the CameraLink standard and are as follows: 9600 baud, 1 start bit, 1 stop bit, no parity, no handshaking.

5 Hardware Interface

5.1 Connectors

5.1.1 CameraLink Connector

The CameraLink cameras are interfaced to external components via

- a CameraLink connector, which is defined by the CameraLink standard as a 26 pin, 0.5" Mini D-Ribbon (MDR) connector to transmit configuration, image data and trigger.
- a subminiature connector for the power supply, 7-pin Binder series 712.

The connectors are located on the back of the camera. Fig. 5.1 shows the plugs and the status LED which indicates camera operation.

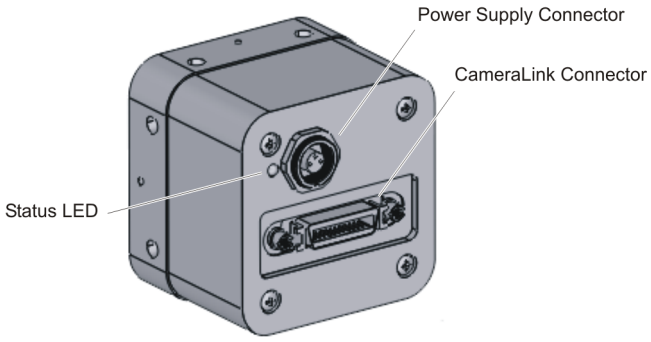

Figure 5.1: Rear view of the CameraLink camera

The CameraLink interface and connector are specified in [CL]. For further details including the pinout please refer to Appendix A. This connector is used to transmit configuration, image data and trigger signals.

5.1.2 Power Supply

The camera requires a single voltage input (see Table 3.4). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear power supplies provide optimum performance.

It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage the camera.

For US and Canada: Ensure a UL listed power supply is used. A suitable UL listed power supply is available from Photonfocus.

For further details including the pinout please refer to Appendix A.

5.1.3 Trigger and Strobe Signals

The power connector contains an external trigger input and a strobe output.

The input voltage to the TRIGGER pin must not exceed +15V DC, to avoid damage to the optocoupler!

In order to use the strobe, the optocoupler must be powered with 5 .. 15 V DC. The STROBE signal is an open-collector output, therefore, the user must connect a pull-up resistor (see Table 5.1) to STROBE_VDD (5 .. 15 V DC) as shown in Fig. 5.2. This resistor should be located directly at the signal receiver.

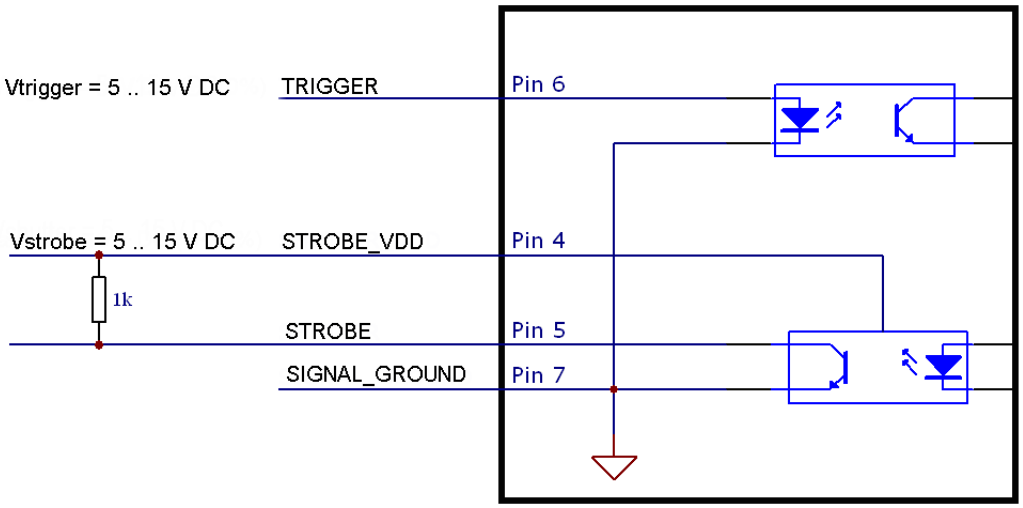

Figure 5.2: Circuit for the trigger input and strobe output signals

The maximum sink current of the STROBE pin is 8 mA. *Do not connect inductive or capacitive loads*, such loads may result in damage of the optocoupler!

STROBE_VDD	Pull-up Resistor
15 V	> 3.9 kOhm
10 V	> 2.7 kOhm
8V	> 2.2 kOhm
7V	> 1.8 kOhm
5V	> 1.0 kOhm

Table 5.1: Pull-up resistor for strobe output

5.1.4 Status Indicator

A dual-color LED on the back of the camera gives information about the current status.

LED Green	Green when an image is output. At slow frame rates, the LED blinks with the FVAL signal. At high frame rates the LED changes to an apparently continuous green light, with intensity proportional to the ratio of readout time over frame time.
LED Red	Red indicates an active serial communication with the camera.

Table 5.2: Meaning of the status indicator

5.2 CameraLink Data Interface

The CameraLink standard contains signals for transferring the image data, control information and the serial communication.

Data signals CameraLink data signals contain the image data. In addition, handshaking signals such as FVAL, LVAL and DVAL are transmitted over the same physical channel.

Camera control information Camera control signals (CC-signals) can be defined by the camera manufacturer to provide certain signals to the camera. There are 4 CC-signals available and all are unidirectional with data flowing from the frame grabber to the camera. For example, the external trigger is provided by a CC-signal (see Table 5.3 for the CC assignment).

CC1	EXSYNC	External Trigger. May be generated either by the frame grabber itself (software trigger) or by en external event (hardware trigger).
CC2	CTRL0	Control0. This signal is reserved for future purposes and is not used.
CC3	CTRL1	Control1. This signal is reserved for future purposes and is not used.
CC4	CTRL2	Control2. This signal is reserved for future purposes and is not used.

Table 5.3: Summary of the Camera Control (CC) signals as used by Photonfocus

Pixel clock The pixel clock is generated on the camera and is provided to the frame grabber for synchronisation.

Serial communication A CameraLink camera can be controlled by the user via an RS232 compatible asynchronous serial interface. This interface is contained within the CameraLink interface and is physically not directly accessible. Refer to Section 4.8 for more information.

The frame grabber needs to be configured with the proper tap and resolution settings, otherwise the image will be distorted or not displayed with the correct aspect ratio. Refer to Section 3.4 for a summarised table of frame grabber relevant specifications. Fig. 5.3 shows symbolically a 1-tap system. For more information about taps refer to [AN021] on the photonfocus website.

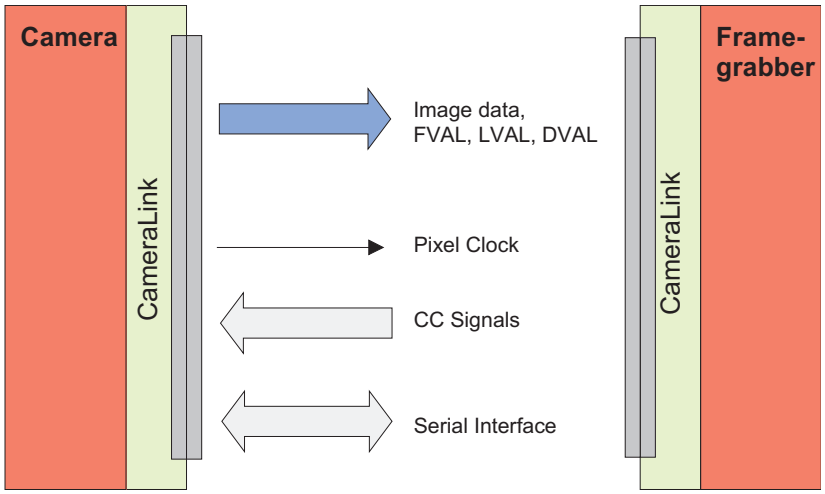

Figure 5.3: 1-tap CameraLink system

5.3 Read-out Timing

5.3.1 Standard Read-out Timing

By default, the camera is in free running mode and delivers images without any external control signals. The sensor is always operated in non-interleaved mode, which means that the sensor is read out after the preset exposure time. Then the sensor is reset, a new exposure starts and the readout of the image information begins again. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active integration phase of the sensor and is shown for clarity only.
Fig. 5.4 visualises the timing behaviour of the control and data signals.

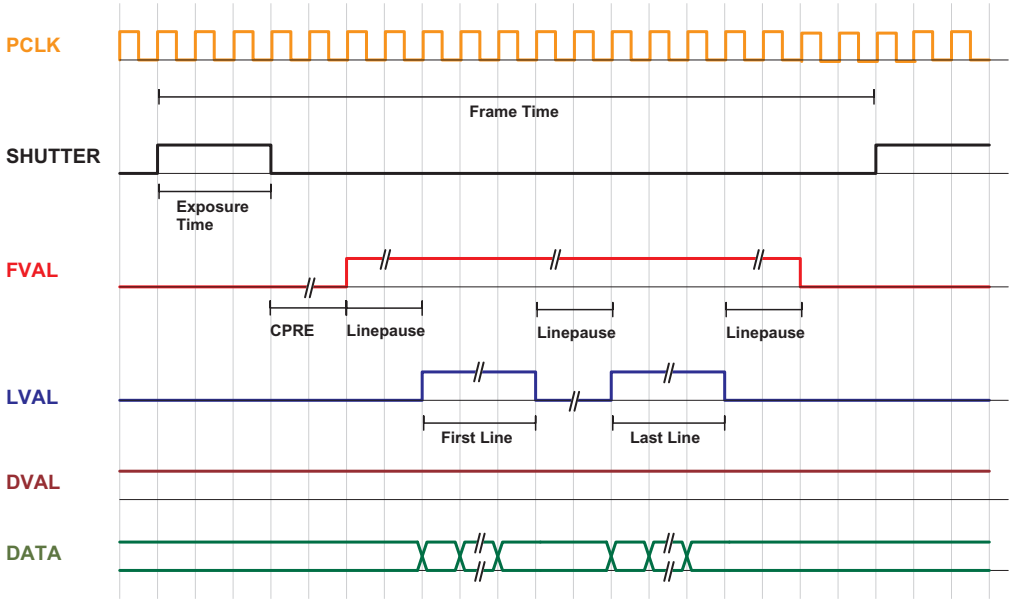

Figure 5.4: Timing diagram frame read-out

Frame time	Maximum frame time is defined as exposure time plus data read out time.
Exposure time	Period during which the pixels are integrating the incoming light.
PCLK	Pixel clock on CameraLink interface.
SHUTTER	Internal signal, shown only for clarity. Is 'high' during the exposure time, during which the pixels integrate the incoming light and the image is acquired.
FVAL (Frame Valid)	Is 'high' while the data of one whole frame are transferred.
LVAL (Line Valid)	Is 'high' while the data of one line are transferred. Example: To transfer an image with 640x480 pixels, there are 480 LVAL within one FVAL active high period. One LVAL lasts 640 pixel clock cycles.
DVAL (Data Valid)	Is 'high' while data are valid.
DATA	Transferred pixel values. Example: For a 100x100 pixel image, there are 100 values transferred within one LVAL active high period, or 100*100 values within one FVAL period.
Line pause	Delay before the first line and after every following line when reading out the image data.

Table 5.4: Explanation of control and data signals used in the timing diagram

These terms will be used also in the timing diagrams of Section 5.4.

5.3.2 Constant Frame Rate (CFR)

When the camera is in constant frame rate mode (not possible together with external trigger), the frame rate can be varied from almost 0 up to the maximum frame rate. Thus, fewer images can be acquired than determined by the frame time. If the exposure and read-out time are smaller than the configured frame time, the camera waits in an idle mode until the frame time has elapsed (see VBlank in Fig. 5.5).

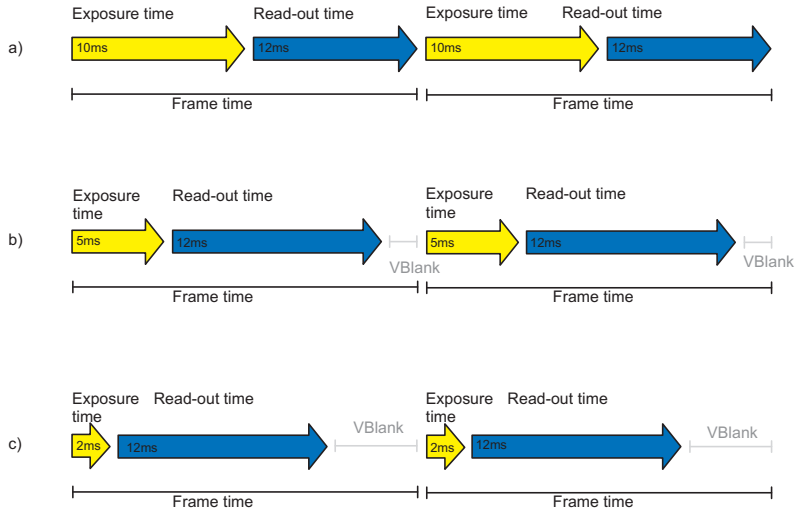

Figure 5.5: Constant Frame Rate = ON

On the other hand, if constant frame rate is switched off, the camera outputs images with maximum speed, depending on the exposure time and the read-out time. The frame rate depends directly on the exposure time.

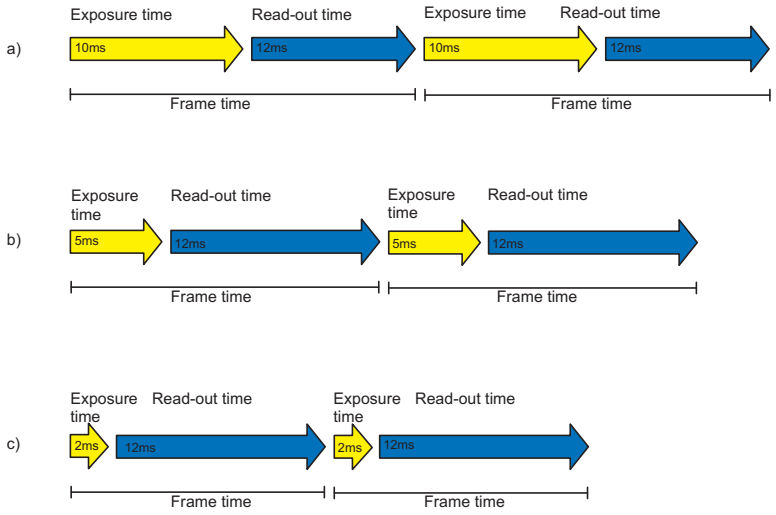

Figure 5.6: Constant Frame Rate = OFF

Constant Frame Rate mode (CFR mode) is not available together with external trigger mode.

5.4 Trigger

5.4.1 Trigger Modes

The following sections show the timing diagram for the trigger modes. The signal ExSync denotes the trigger signal that is provided either by the interface trigger or the I/O trigger (see Section 4.6). The other signals are explained in Table 5.4.

Camera-controlled Exposure

In the camera-controlled trigger mode, the exposure is defined by the camera and is configurable by software. For an active high trigger signal, the image acquisition begins with the rising edge of the trigger signal. The image is read out after the pre-configured exposure time. After the readout, the sensor returns to the reset state and the camera waits for a new trigger pulse (see Fig. 5.7).
The data is output on the rising edge of the pixel clock, the handshaking signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER in Fig. 5.7 indicates the active integration phase of the sensor and is shown for clarity only.

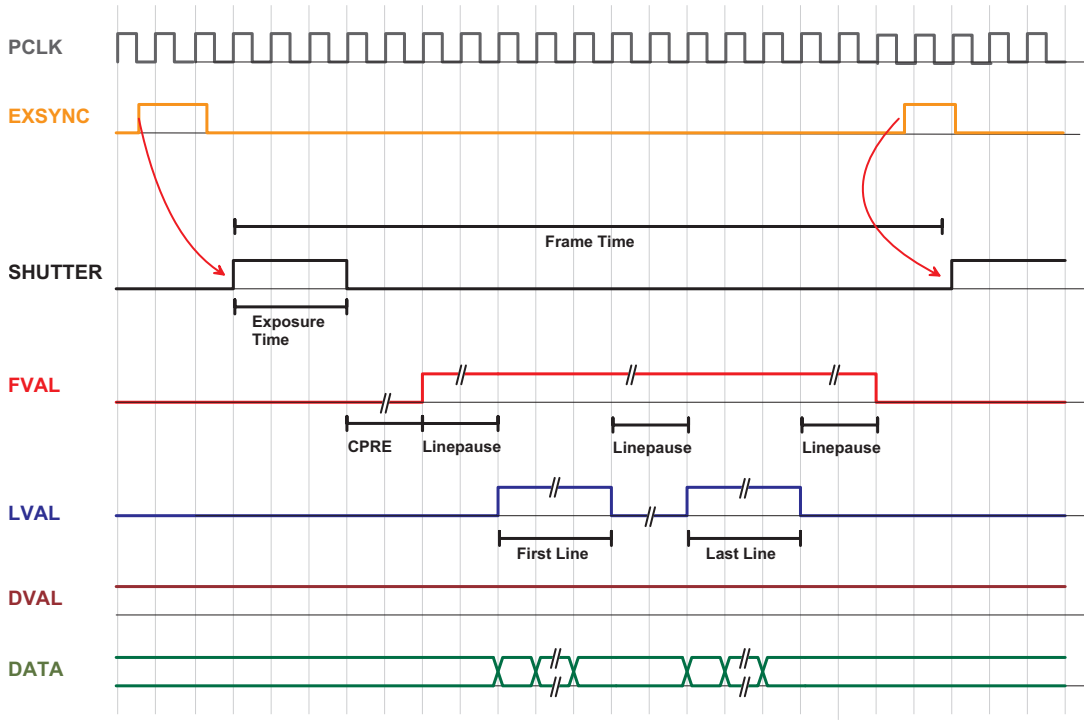

Figure 5.7: Trigger timing diagram for camera-controlled exposure

Level-controlled Exposure

In the level-controlled trigger mode, the exposure is defined by the pulse width of the trigger signal. For an active high trigger signal, the image acquisition begins with the rising edge and stops with the falling edge of the trigger signal. Then the image is read out. After that, the sensor returns to the reset state and the camera waits for a new trigger pulse (see Fig. 5.8). The data is output on the rising edge of the pixel clock, the handshaking signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER in Fig. 5.8 indicates the active integration phase of the sensor and is shown for clarity only.

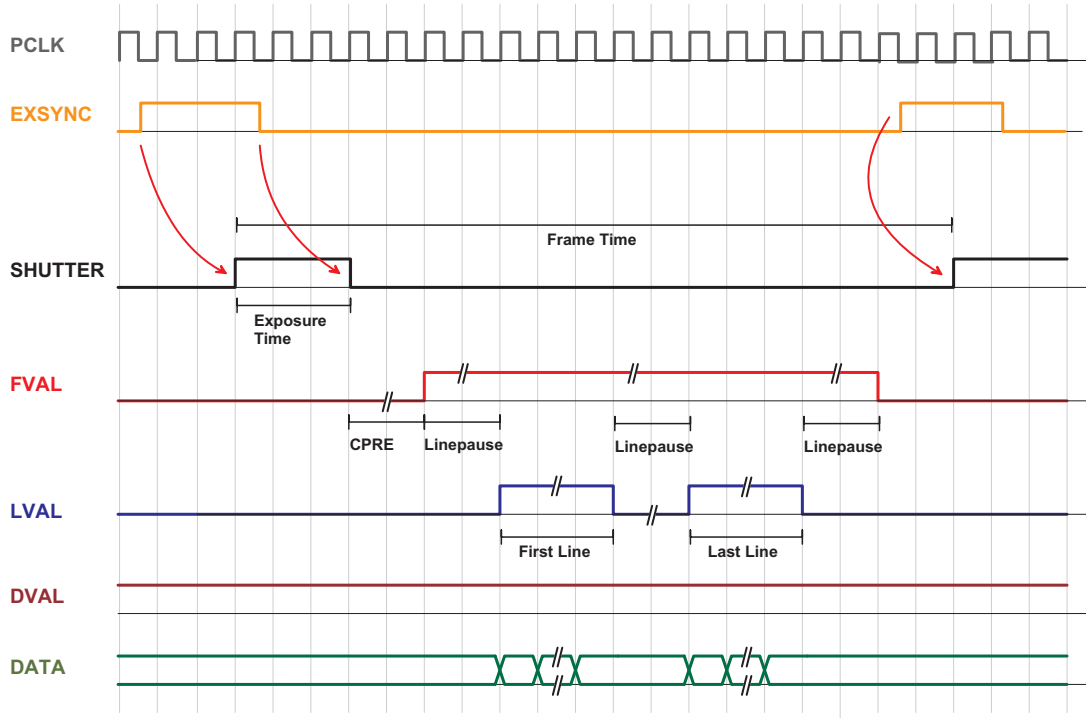

Figure 5.8: Trigger timing diagramm for level controlled exposure

5.4.2 Trigger Delay

The total delay between the trigger edge and the camera exposure consists of the delay in the frame grabber and the camera (Fig. 5.9). Usually, the delay in the frame grabber is relatively large to avoid accidental triggers caused by voltage spikes (see Fig. 5.10). The trigger can also be delayed by the Trigger-Delay Register in the camera. For further information refer to Section 6.4.3
For the delay in the frame grabber, please ask your frame grabber manufacturer. The camera delay consists of a constant trigger delay and a variable delay (jitter). Refer to Table 5.5 for the model-specific values.

Camera Model	Camera Trigger Delay (constant)	Max. Camera Trigger Jitter
HURRICANE-40 / THUNDER-90	150 ns	25 ns

Table 5.5: Maximum camera trigger delay

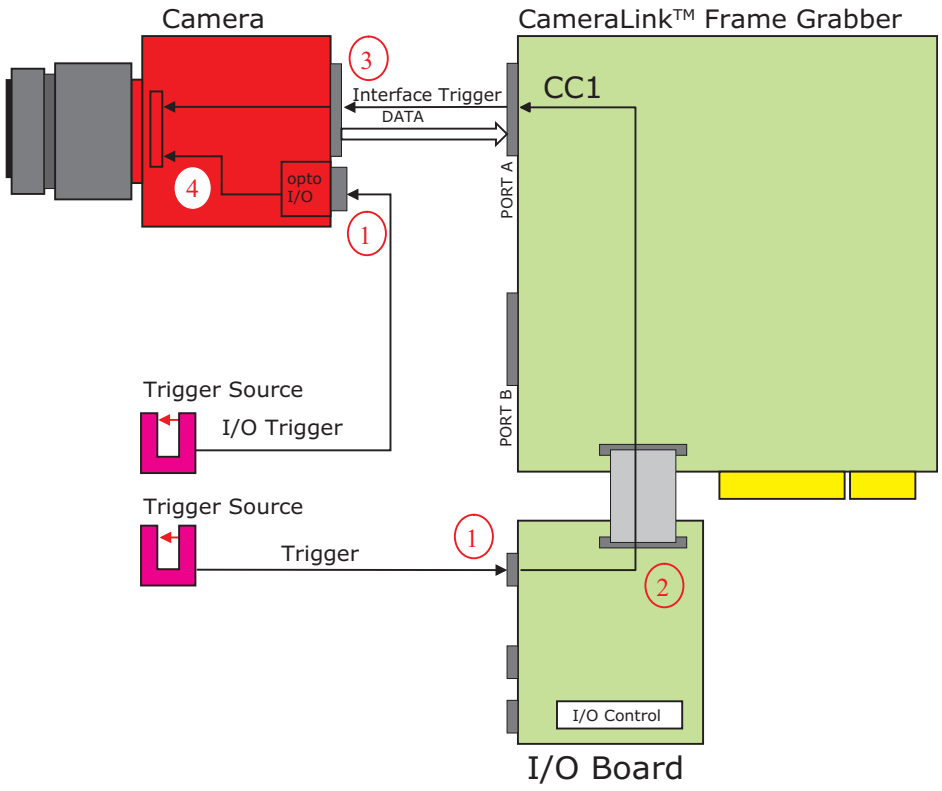

Figure 5.9: Trigger Delay visualisation from the trigger source to the camera

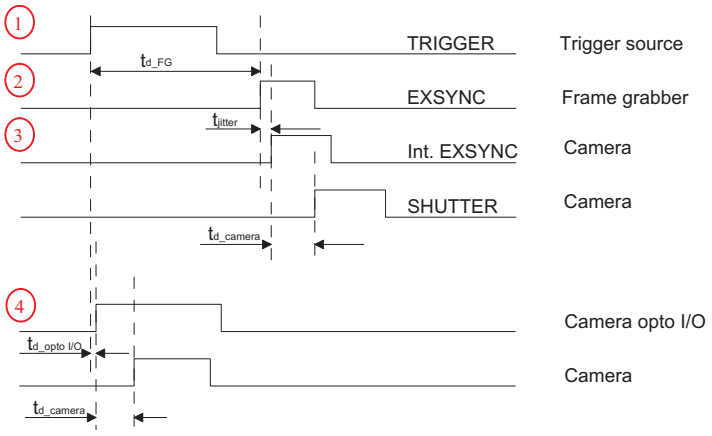

Figure 5.10: Timing Diagram for Trigger Delay

6 The PFRemote Control Tool

6.1 Overview

PFRemote is a graphical configuration tool for Photonfocus cameras. The latest release can be downloaded from the support area of www.photonfocus.com. All Photonfocus cameras can be either configured by PFRemote, or they can be programmed with custom software using the PFLib SDK. PFRemote is available for Windows only. For a Linux or QNX system, we provide the necessary source code to control the camera on request, but there is no graphical user interface available.
As shown in Fig. 6.1, PFRemote and PFLib respectively control parameters of the camera, such as exposure time and ROI. However, to grab an image and to process it use the software or SDK that was delivered with your frame grabber.

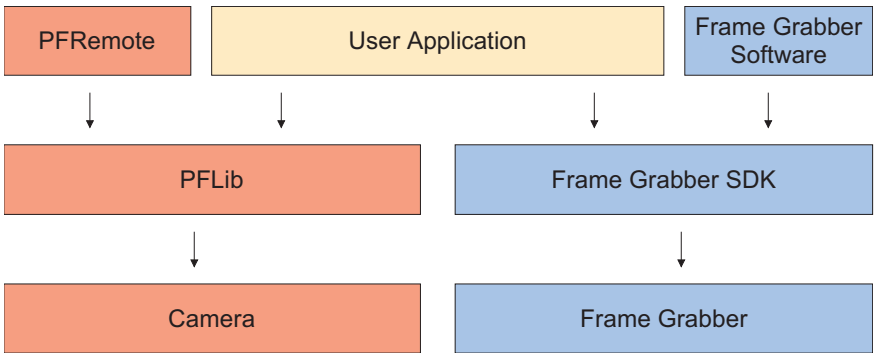

Figure 6.1: PFRemote and PFLib in context with the CameraLink frame grabber software

6.1.1 Operating System

PFRemote is available for Windows only. For a Linux or QNX system, please contact us.

6.2 Installation Notes

Before installing PFRemote, make sure that your frame grabber software is installed correctly. The PFRemote setup wizard will ask you to choose your frame grabber. You will then have to copy the necessary files from your frame grabber installation to the `\PFRemote` directory.
If your CameraLink compatible frame grabber is not listed in the setup wizard, please do the following:

- During PFRemote installation, choose "Other CameraLink compliant Grabber" when asked about the frame grabber.
- After the installation, locate a `CLSER*.DLL` in your frame grabber's software distribution (* matches any vendor specific extension). This file is usually located in your `\windows\system32` directory or in the installation directory of the frame grabber software.
- Copy the `CLSER*.DLL` into the PFRemote installation directory (usually `C:\Program Files\PFRemote`) and rename it to `CLSER.DLL`.
- Start PFRemote. The port names "`cl0`" and "`cl1`" are displayed.

6.2.1 DLL Dependencies

Several DLLs are necessary in order to be able to communicate with the cameras:

- `MVXXXXE.DLL`: Specific camera DLL, e.g. HURRICANE.DLL.
- `PFCAM.DLL`: DLL handling camera detection and switching to specific camera DLL.
- `CLSER.DLL`: DLL for serial communication. This is a DLL which is delivered with your frame grabber software.
- `COMDLL.DLL`: Communication DLL. This `COMDLL` is not necessarily CameraLink specific, but may depend on a CameraLink API compatible DLL which should also be provided by your frame grabber manufacturer (as described above).

More information about these DLLs is available in the SDK documentation ([SW002]).

6.3 Graphical User Interface (GUI)

PFRemote consists of a main window (Fig. 6.2) and a configuration dialog. In the main window, the camera port can be opened or closed, and log messages are displayed. The configuration dialog appears as soon as a camera port was opened successfully and can be used to configure the camera properties.
The following sections describe the general structure of PFRemote.

6.3.1 Menu

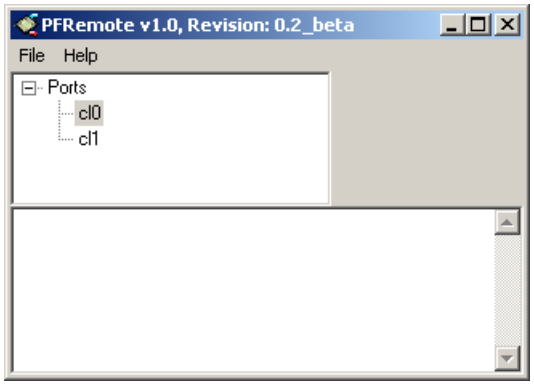

Figure 6.2: PFRemote main window

In the PFRemote main window, there are two menus with the following entries available:

File Menu

Clear Log Clears the log file buffer, see more below

Quit Leave the program

Help Menu

About Copyright notice and version information

Help F1 Invoke the online help

6.3.2 Ports, Device initialization

After starting **PFRemote**, the main window as shown in Fig. 6.2 will appear. In the PortBrowser in the upper left corner you will see a list of supported ports.

Depending on the configuration, your port names may differ, and not every port may be functional.

After connecting the camera, the device can be opened with a double click on the port name or by right-clicking on the port name and choosing **Open & Configure**. If the initialisation of the camera was successful, the configuration dialog will open. The device is closed when PFRemote is closed. Alternatively, e.g. when connecting another camera or evaluation kit, the device can also be closed explicitely by right clicking on the port name and choosing **Close**; make sure that the configuration dialog is closed prior to closing the port.
Errors, warnings or other important activities are logged in a log window on the bottom of the main window.
If the device does not open, check the following:

- Is the power LED active? Do you get an image in the display software?
- Verify all cable connections.
- Check the communication LED: do you see some activity when you try to access the camera?

6.3.3 Main Buttons

The buttons on the right side of the configuration dialog store and reset the camera configuration.

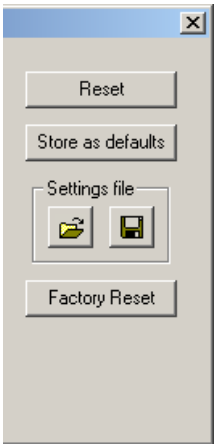

Figure 6.3: Main buttons

Reset Reset the camera and load the default configuration.

Store as defaults Store the current configuration in the camera flash memory as default configuration. After a reset, the camera will load this configuration by default.

Settings file: File Load Load a stored configuration from a file.

Settings file: File Save Save current configuration to a file.

Factory Reset Reset camera and reset the configuration to the factory defaults.

6.4 Usage

The following sections describe the available features in PFRemote of the camera. The sections are grouped according to the panel tabs in the configuration dialog.

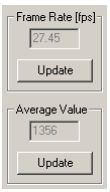

Figure 6.4: HURRICANE-40 frame rate and average value

Frame Rate [fps] Show the actual frame rate of the camera in frames per second.

Update To update the value of the frame rate, click on this button.

Average Value Grayscale average of the actual images. This value is in 12bit (0...4095).

Update To update the value of the average, click on this button.

6.4.1 Exposure

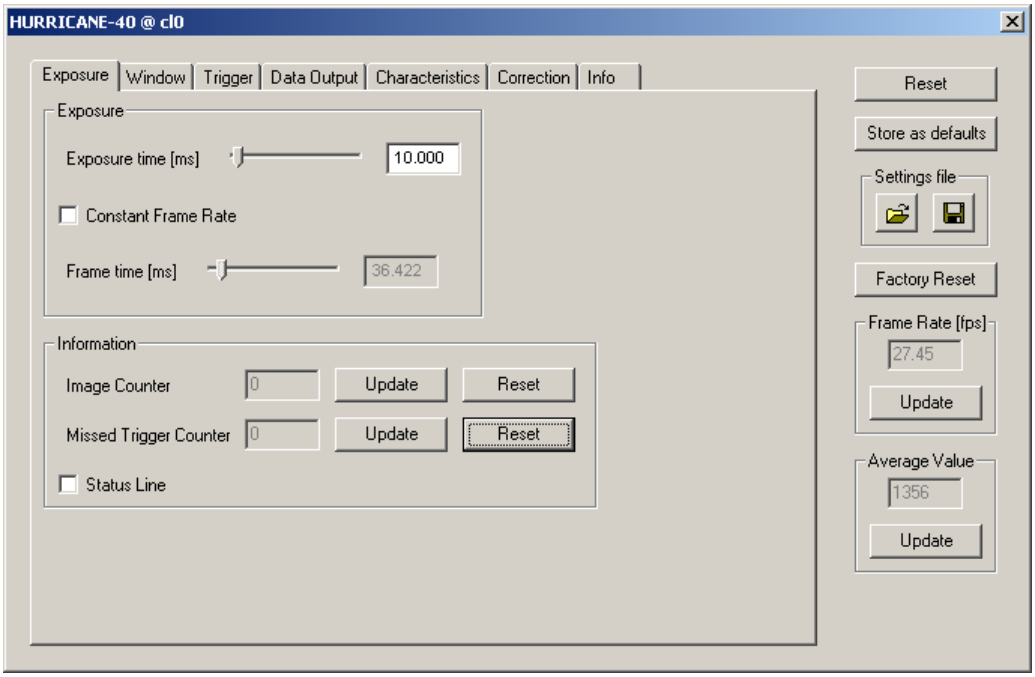

Figure 6.5: Exposure panel

This panel contains exposure and information settings.

Exposure time Configure the exposure time in milliseconds.

Constant Frame Rate When the Constant Frame Rate is switched on, the frame rate (number of frames per second) can be varied from almost 0 up to the maximum frame rate. Thus,

fewer images can be acquired than would otherwise be possible. When Constant Frame Rate is switched off, the camera delivers images as fast as possible, depending on the exposure time and the read-out time. See Section 5.3.2.

Frame time Configure the frame time in millisecond. Only availble if Constant Frame Rate is enabled. The minimal frame time depends on the exposure and readout time.

The Information properties provide information about the acquired images (see Section 4.2).

Image Counter 24 bit real-time counter. Incremented by 1 for every new image.

Missed Trigger Counter Counter for trigger pulses that were ignored because the trigger pulse was received during image exposure or readout. In free-running mode it counts all pulses received from interface trigger and I/O trigger.

Status Line The status line replaces the last line of an image with image information. Refer to the User Manual.

To update the value of the information properties, click on the Update-Button; to reset the properties, click on the Reset-Button.

6.4.2 Window

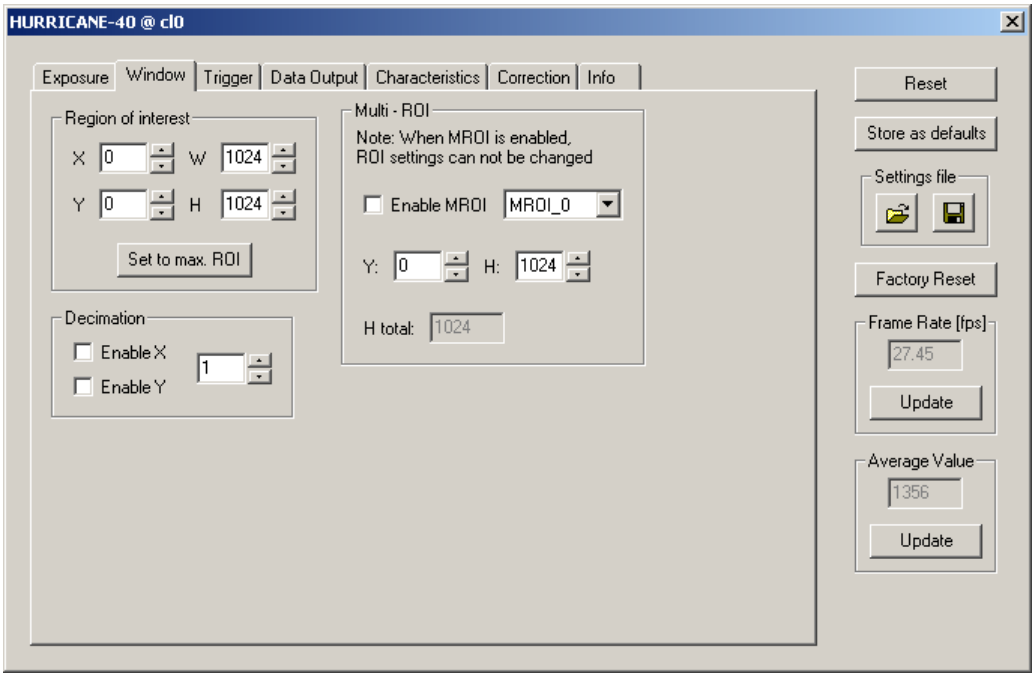

Figure 6.6: Window panel

Region of Interest

Region of interest
The region of interest (ROI, see Section 4.5.1) is defined as a rectangle (X, Y), (W, H) where

X X-coordinate, starting from 0 in the upper left corner

Y Y-coordinate, starting from 0 in the upper left corner

W Window width

H Window height

Set to max ROI Set Window to maximal ROI. (X=0; Y=0; W=1024; H=1024)

Decimation

Decimation
`Decimation` reduces the number of pixels in x- or y-direction or both. Decimation can also be used together with a ROI or MROI. Decimation in y-direction transfers every n-th row only and directly results in reduced read-out time and higher frame rate respectively. Decimation in x-direction transfers every pixel of a row, but uses the CameraLink `DVAL` (data valid) signal to indicate which pixels to mask (see Section 4.5.3). Therefore it can not be used to increase the frame rate

Please consult the documentation of your frame grabber on how to configure the frame grabber such that it interpretes the DVAL signal.

Enable X Enable decimation in x-direction.

Enable Y Enable decimation in y-direction.

Value Decimation factor. Example: Value = 4 reads every fourth row and fourth column respectively only.

Multi - ROI

MROI
The camera can handle up to 16 different regions of interest (see Section 4.5.2). The multiple ROIs are joined together and form a single image, which is transferred to the frame grabber. An ROI is defined by its starting value in y-direction and its height. Width and horizontal offset are specified by `X` and `W` settings. The maximum frame rate in MROI mode depends on the number of rows and columns being read out. Overlapping ROIs are allowed, and the total height may exceed 1024 rows.

Enable MROI If MROI is enabled, the ROI and MROI settings cannot be changed.

MROI_X Select one of the MROI settings.

Y Y-coordinate of the selected MROI. If Y is set to 1023, this and all further MROI settings will be ignored.

H Height of the selected MROI.

H tot Shows the sum of all MROIs as the total image height.

After changing a property, always press Enter in order to make the change active.

6.4.3 Trigger

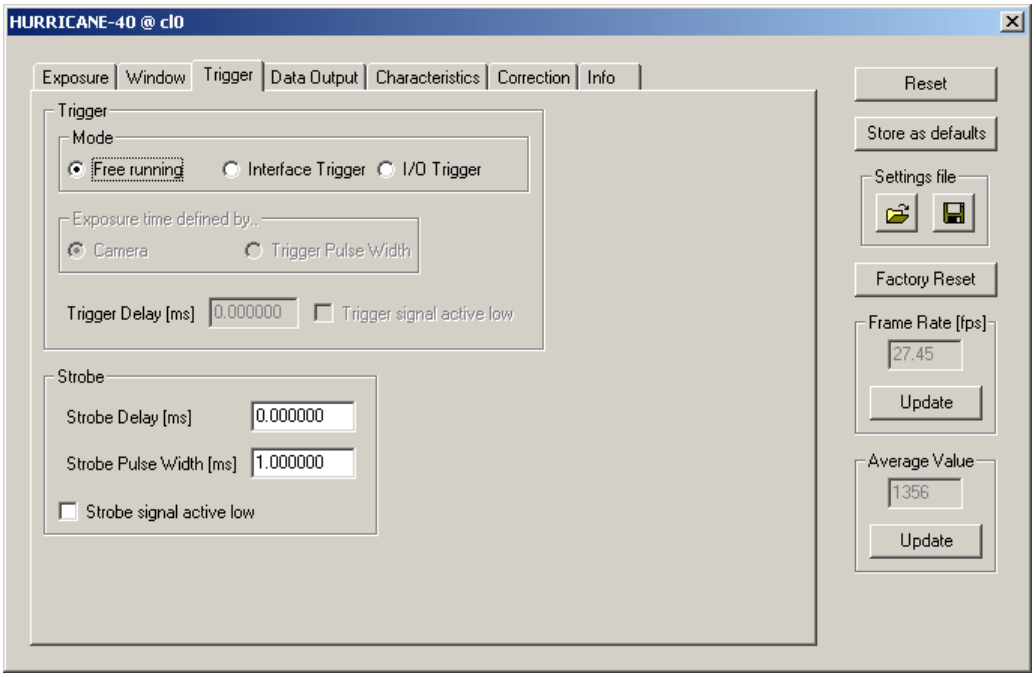

Figure 6.7: Trigger panel

Trigger

Free running The camera continuously delivers images with a certain configurable frame rate.

Interface Trigger The Trigger signal is applied to the camera by the CameraLink frame grabber or the USB interface (if available) respectively.

I/O Trigger The trigger signal is applied directly at the camera on the power supply connector.

Exposure time defined by Camera The exposure time is defined by the value of the exposure time camera register.

Exposure time defined by Trigger Pulse Width The exposure time is defined by the pulse width of the trigger signal (Level controlled exposure).

This property disables LinLog.

Trigger Delay Programmable delay in milliseconds between the incoming trigger edge and the start of the exposure.

Trigger signal active low Define the trigger signal to be active high (default) or active low.

For more information about the trigger refer to Section 4.6.

Strobe

The camera generates a strobe output signal that can be used to trigger a strobe (see Section 5.1.3). The delay, pulse width and polarity can be defined by software.

Strobe Delay Delay in milliseconds from the input trigger edge to the rising edge of the strobe output signal.

Strobe Pulse Width The pulse width of the strobe trigger in milliseconds.

Strobe signal active low Define the strobe output to be active high (default) or active low.

☞ To turn off strobe output set strobe pulse width to 0

6.4.4 Data Output

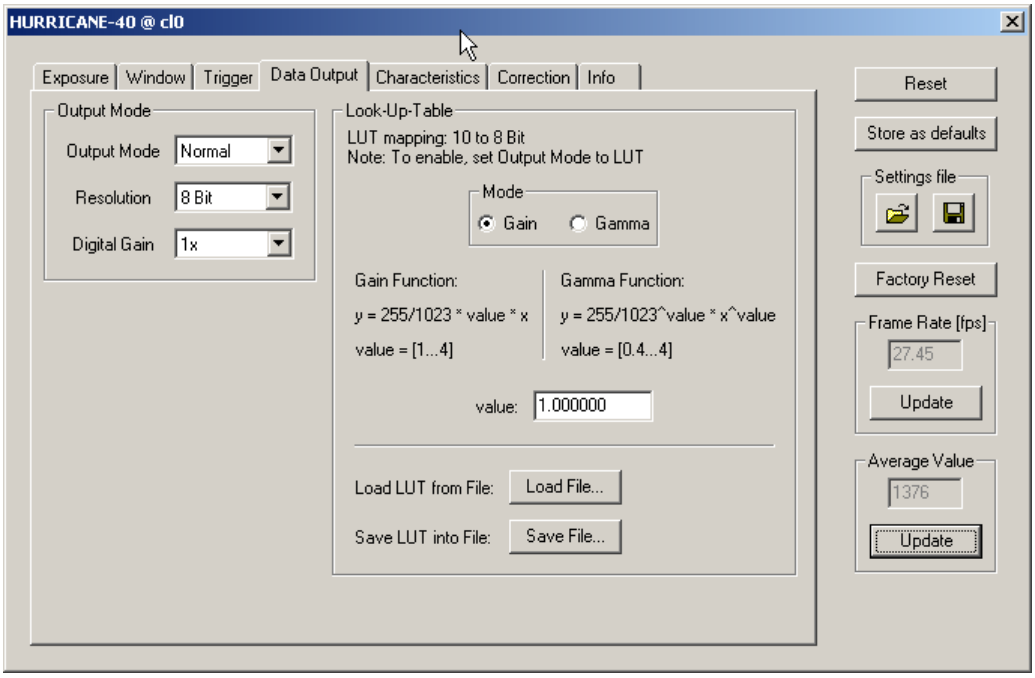

Figure 6.8: Data output panel

Output Mode

Output Mode:

Normal Normal mode.

LFSR Test image. Linear feedback shift register (pseudo-random image). The pattern depends on the gray level resolution (see Section 4.3.5).

Ramp Test image. Values of pixel are incremented by 1, starting at each row. The pattern depends on the gray level resolution (see Section 4.3.5).

LUT Look-Up-Table, a 10-to-8-bit mapping of gray levels.

Resolution:

8 Bit Gray level resolution of 8 bit.

10 Bit Gray level resolution of 10 bit.

12 Bit Gray level resolution of 12 bit.

Digital Gain:

1x No digital gain, normal mode.

2x Digital gain 2.

4x Digital gain 4.

Look-Up-Table

Gray level transformation is remapping of the gray level values of an input image to new values which transform the image in some way. The look-up table (LUT) is used to convert the grayscale value of each pixel in an image into another gray value. It is typically used to implement a transfer curve for contrast expansion.
The HURRICANE camera perform a 10-to-8-bit mapping, so that 1024 input gray levels can be mapped to 256 output gray levels. (0 to 1023 and 0 to 255)
The default LUT is a gain function with value = 1.
LUT Mode:

Gain Linear function. Y = 255 / 1023 * value * X; Valid range for `value` [1...4].

Gamma Gamma function. Y = 255 / 1023^value * X ^ value; Valid range for `value` [0.4...4].

value Enter a value. the LUT will be calculated and downloaded to the camera.

User LUT: Load File Load a user defined LUT - file (*.txt, tab delimited). There is an example in the PFRemote directory (hurricane40_lut.txt).

It is also possible to load a user LUT-file with missing input values (LUT-addresses). Then only pixel values corresponding to listed LUT entries will be overwritten. Example of a user defined LUT file:

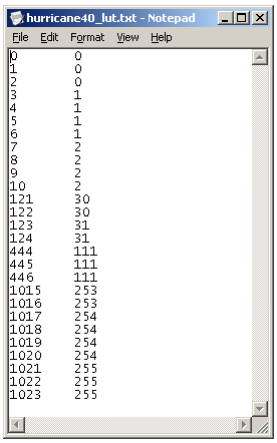

Figure 6.9: Example of a user defined LUT file

6.4.5 Characteristics

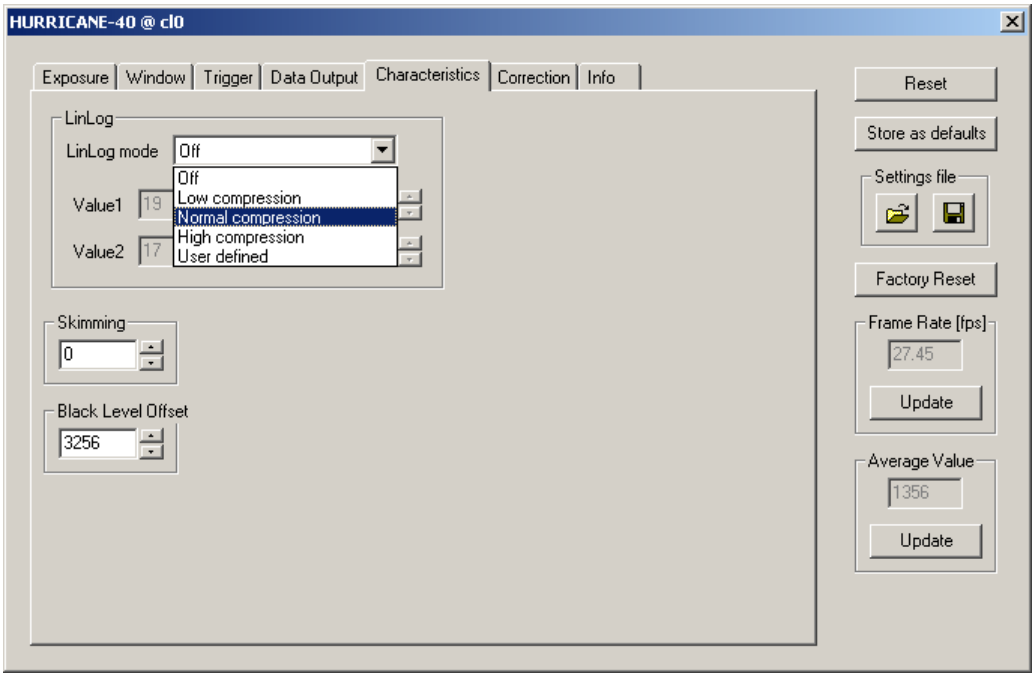

Figure 6.10: Characteristics panel

LinLog

Please read Section 4.3.2 for more information about LinLog. There are 3 predefined LinLog settings available. Alternatively, custom settings can be defined in the `User defined` Mode.

LinLog Mode Off: LinLog is disabled Low/Normal/High compression: Three LinLog presettings. User defined: `Value1`, `Time1`, `Value2` and `Time2` (user defined - please read the User Manual for a more detailled explanation).

Skimming

For more information see Section 4.3.3.

Skimming Skimming value. If 0, Skimming is disabled.

Black Level Offset

Black Level Offset Black level offset value. Use this to adjust the black level of the image at no illumination (see Section 4.3.1).

6.4.6 Correction

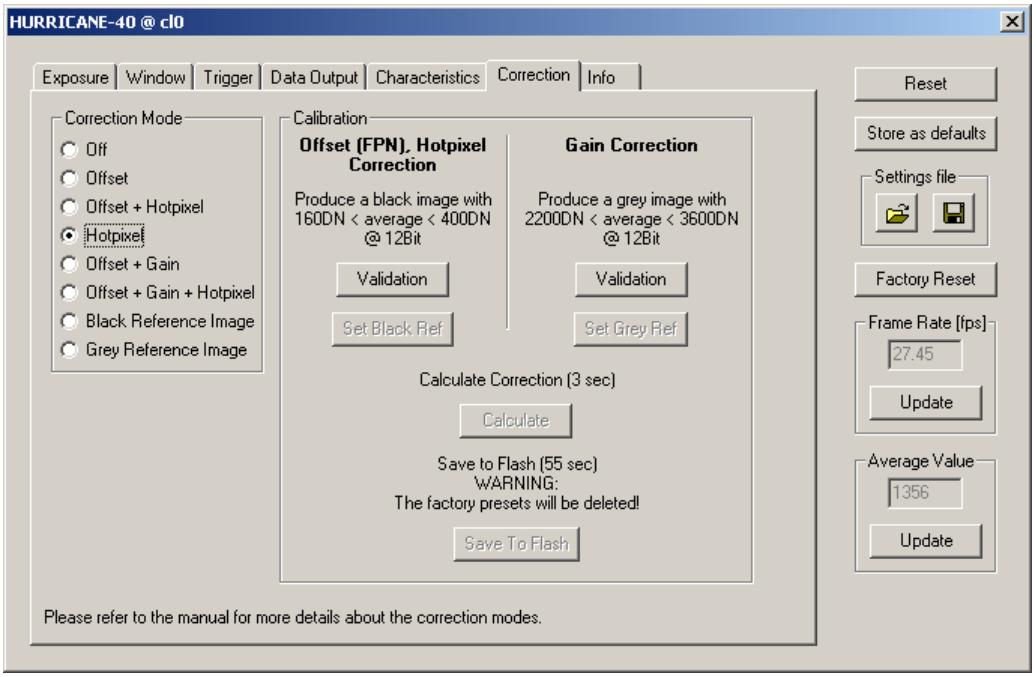

Figure 6.11: Correction panel

Correction Mode

For more information about the image correction, see Section 4.4.

Off No correction.

Offset Activate offset correction

Offset + Hotpixel Activate offset and hot pixel correction

Hotpixel Activate hot pixel correction

Offset + Gain Activate offset and gain correction

Offset + Gain + Hotpixel Activate offset, gain and hot pixel correction.

Black Reference Image Output the black refernece image that is currently stored in the camera RAM (for debug purpose).

Gray Reference Image Output the gray reference image that is currently stored in the camera RAM (for debug purpose).

Calibration

Offset (FPN), Hotpixel Correction The offset correction is based on a black reference image, which is taken at no illumination (e.g. lens aperture completely closed). The black reference image contains the fixed-pattern noise of the sensor, which can be subtracted from the live images in order to minimize the static noise. Close the lens of the camera. Click on the Validation button. If the Set Black Ref - button is still inactive, the average of the image is out of range. Change to panel Characteristics and change the Property `BlackLevelOffset` until the average of the image is between 160 and 400DN. Click again on the Validation button and then on the Set Black Ref Button. If only offset and hotpixel Correction is needed it is not necessary to calibrate a gray image. In this case leave out the next step (Gain Correction) and continue with the step Calculate

Gain Correction The gain correction is based on a gray reference image, which is taken at uniform illumination to give an image with a mid gray level.

Gain correction is not a trivial feature. The quality of the gray reference image is crucial for proper gain correction.

Produce a gray image with an average between 2200 and 3600DN. Click on the Validation button to check the average. If the average is in range, the Set Gray Ref button is active.

Calculate Calculate the correction values into the camera RAM. To make the correction values permanent, use the 'Save to Flash' button.

Save to Flash Save the caculated values to the internal flash memory. This will overwrite the factory presets.

6.4.7 Info

This panel shows camera specific information such as type code, serial number and firmware revision of the FPGA and microcontroller.

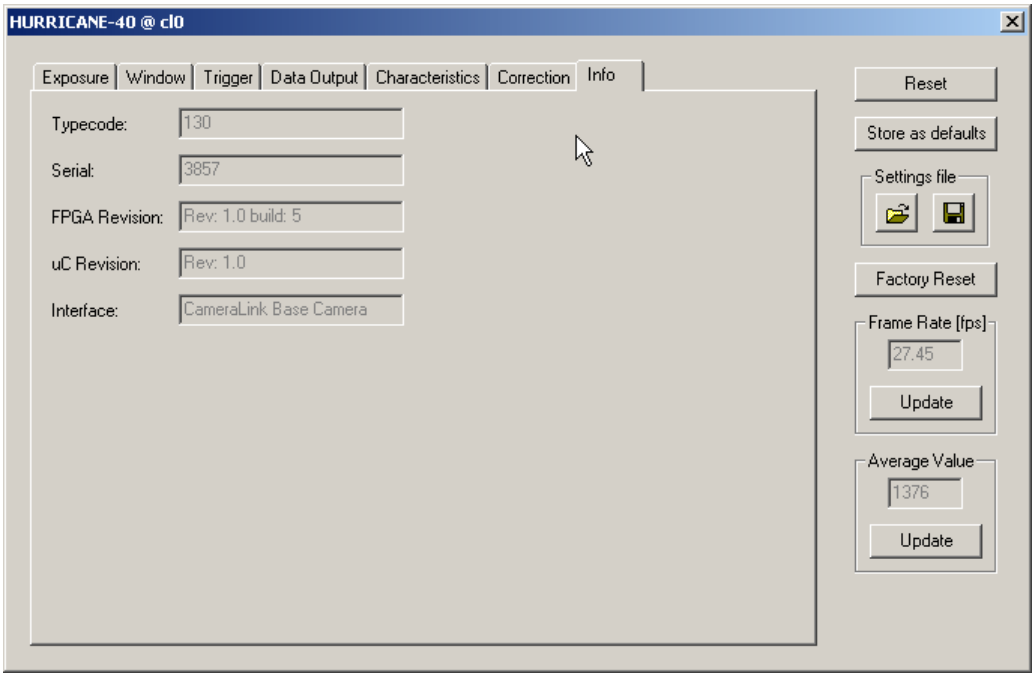

Figure 6.12: Info panel

Typecode Type code of the connected camera.

Serial Serial number of the connected camera.

FPGA Revision Firmware revision of built-in FPGA of the connected camera.

uC Revision Firmware revision of built-in microcontroller of the connected camera.

☞ When contacting the Photonfocus support, please enclose the information provided on this panel.

7

Mechanical and Optical Considerations

7.1 Mechanical Interface

The general mechanical data of the cameras are listed in section 3, Table 3.4.
During storage and transport, the camera should be protected against vibration, shock, moisture and dust. The original packaging protects the camera adequately from vibration and shock during storage and transport. Please either retain this packaging for possible later use or dispose of it according to local regulations.

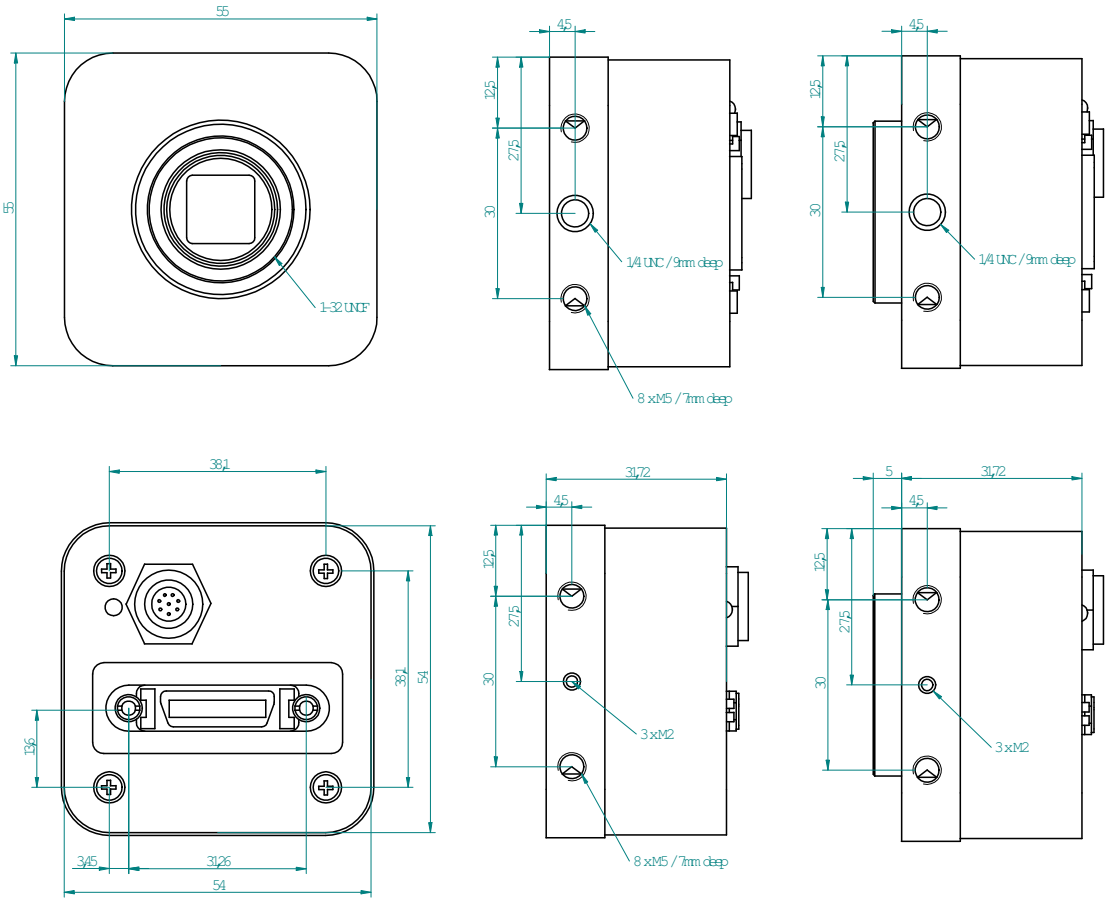

Figure 7.1: Mechanical dimensions of the CameraLink model with or without C-Mount adapter

All values are in [mm].

7.2 Optical Interface

7.2.1 Mounting the Lens

Remove the protective cap from the C-/CS-mount thread of the camera and install the lens. When removing the protective cap or changing the lens, the camera should always be held with the opening facing downwards to prevent dust from the environment falling onto the CMOS sensor. If the lens is removed, the protective cap should be refitted. If the camera is operated in a dusty environment, we recommend the use of a constant stream of clean air at the front of the objective.

7.2.2 Cleaning the Sensor

The sensor is part of the optical path and should be handled like other optical components: with extreme care.
Dust can obscure pixels, producing dark patches in the images captured. Dust is most visible when the illumination is collimated. Dark patches caused by dust or dirt shift position as the angle of illumination changes. Dust is normally not visible when the sensor is positioned at the exit port of an integrating sphere, where the illumination is diffuse.

1. The camera should only be cleaned in ESD-safe areas by ESD-trained personnel using wrist straps. Ideally, the sensor should be cleaned in a clean environment. Otherwise, in dusty environments, the sensor will immediately become dirty again after cleaning.
2. Use a high quality, low pressure air duster (e.g. Electrolube EAD400D compressed air spray) to blow off loose particles. This step alone is usually sufficient to clean the sensor of the most common contaminants.

   Workshop air supply is not appropriate and may cause permanent damage to the sensor.

3. If further cleaning is required, use a suitable lens wiper or Q-Tip moistened with an appropriate cleaning fluid to wipe the sensor surface as described below. Examples of suitable lens cleaning materials are given in Table 7.1. Cleaning materials must be ESD-safe, lint-free and free from particles that may scratch the sensor surface.

   Do not use ordinary cotton buds. These do not fulfil the above requirements and permanent damage to the sensor may result.

4. Wipe the sensor carefully and slowly. First remove coarse particles and dirt from the sensor using Q-Tips soaked in 2-propanol, applying as little pressure as possible. Using a method similar to that used for cleaning optical surfaces, clean the sensor by starting at any corner of the sensor and working towards the opposite corner. Finally, repeat the procedure with methanol to remove streaks. It is imperative that no pressure be applied to the surface of the sensor or to the black globe-top material (if present) surrounding the optically active surface during the cleaning process.

Product		Supplier	Remark
Anticon Gold 9"x 9"	Wiper	Milliken	ESD safe and suitable for class 100 environments.
TX4025	Wiper	Texwipe	
Transplex	Swab	Texwipe	
Small Q-Tips SWABS BB-003	Q-tips	Hans J. Michael GmbH, Germany	
Large Q-Tips SWABS CA-003	Q-tips	Hans J. Michael GmbH, Germany	
Point Slim HUBY-340	Q-tips	Sharp	
Methanol	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.9% min (Assay), Merk 12,6024, UN1230, slightly flammable and poisonous.
2-Propanol (Iso-Propanol)	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.5% min (Assay) Merk 12,5227, UN1219, slightly flammable.

Table 7.1: Recommended materials for sensor cleaning

For cleaning the sensor, Photonfocus recommends the products available from the suppliers as listed in Table 7.1.

7.3 Compliance

CE Compliance Statement

We,

Photonfocus AG,

8853 Lachen, Switzerland

declare under our sole responsibility that the following products:

MV-D1024-28-CL-10, MV-D1024-80-CL-8, MV-D1024-160-CL-8

MV-D1024x128-28-CL-10, MV-D1024x128-80-CL-8,
MV-D1024x128-160-CL-8

MV-D752-28-CL-10, MV-D752-80-CL-8, MV-D752-160-CL-8

MV-D640-33-CL-10, MV-D640-66-CL-10, MV-D640-48-U2-10
MV-D640C-33-CL-10, MV-D640C-66-CL-10, MV-D640C-48-U2-10

HURRICANE-40, THUNDER-90, BLIZZARD-60 (CameraLink Models)
HURRICANE-40, THUNDER-90 (USB2.0 Models)

Digipeater CLB26

are in compliance with the below mentioned standards according to the provisions of European Standards Directives:

EN 61 000 – 6 – 3 : 2001
EN 61 000 – 6 – 2 : 2001
EN 61 000 – 4 – 6 : 1996
EN 61 000 – 4 – 4 : 1996
EN 61 000 – 4 – 3 : 1996
EN 61 000 – 4 – 2 : 1995
EN 55 022 : 1994

René Mangold
Marketing & Sales

Dr. Peter Mario Schwider
CTO

October 2005

Figure 7.2: CE Compliance Statement

8 Warranty

The manufacturer alone reserves the right to recognize warranty claims.

8.1 Warranty Terms

The manufacturer warrants to distributor and end customer that for a period of two years from the date of the shipment from manufacturer or distributor to end customer (the "Warranty Period") that:

- the product will substantially conform to the specifications set forth in the applicable documentation published by the manufacturer and accompanying said product, and
- the product shall be free from defects in materials and workmanship under normal use.

The distributor shall not make or pass on to any party any warranty or representation on behalf of the manufacturer other than or inconsistent with the above limited warranty set.

8.2 Warranty Claim

The above warranty does not apply to any product that has been opened, modified or altered by any party other than manufacturer, or for any defects caused by any use of the product in a manner for which it was not designed, or by the negligence of any party other than manufacturer.

9

References

All referenced documents can be downloaded from our website at www.photonfocus.com.

CL CameraLink Specification, October 2000

SW002 PFLib Documentation, Photonfocus, August 2005

AN001 Application Note "LinLog", Photonfocus, December 2002

AN024 Application Note "LinLog - Principle and Practical Example", Photonfocus, March 2005

AN007 Application Note "Camera Acquisition Modes", Photonfocus, March 2004

AN010 Application Note "Camera Clock Concepts", Photonfocus, July 2004

AN021 Application Note "CameraLink", Photonfocus, July 2004

AN026 Application Note "LFSR Test Images, Photonfocus, September 2005

A

Pinouts

A.1 Power Supply

The power supply plugs are available from Binder connectors at www.binder-connector.de.

It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage or destroy the camera.

For US and Canada: Ensure a UL listed power supply is used. A suitable UL listed power supply is available from Photonfocus.

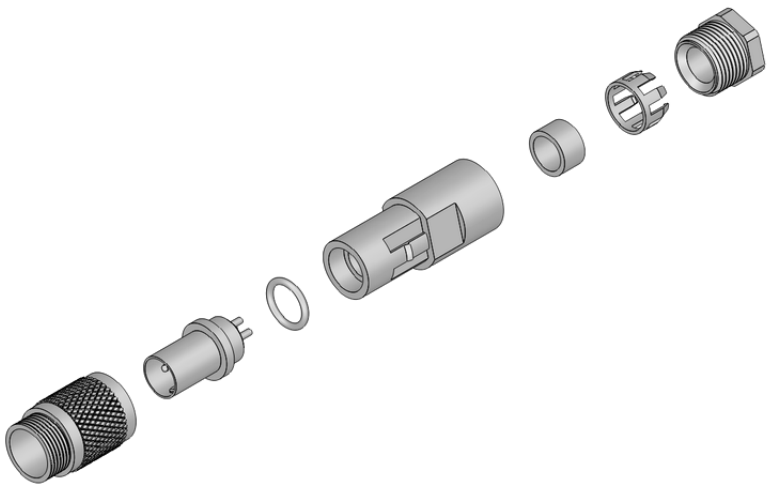

Figure A.1: Power connector assembly

A.1.1 Power Supply Connector

Connector Type	Order Nr.
7-pole, plastic	99-0421-00-07
7-pole, metal	99-0421-10-07

Table A.1: Power supply connectors (Binder subminiature series 712)

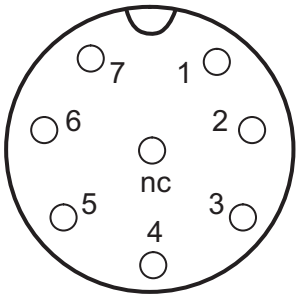

Figure A.2: Power supply plug, 7-pole (rear view of plug, solder side)

Pin	*I/O Type*	*Name*	*Description*
1	PWR	VDD	+12 V DC (± 10%)
2	PWR	GND	Ground
3	O	RESERVED	Do not connect
4	PWR	STROBE-VDD	+5 .. +15 V DC
5	O	STROBE	Strobe control (opto-isolated)
6	I	TRIGGER	External trigger (opto-isolated), +5 .. +15V DC
7	PWR	GROUND	Signal ground (for opto-isolated strobe signal)

Table A.2: Power supply plug pin assignment

A.2 CameraLink

The pinout for the CameraLink 26 pin, 0.5" Mini D-Ribbon (MDR) connector is according to the CameraLink standard ([CL]) and is listed here for reference only.

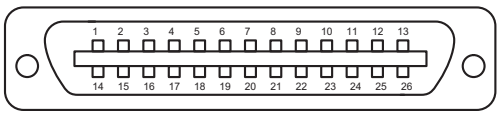

Figure A.3: CameraLink cable 3M MDR-26 plug (both ends)

PIN	IO	Name	Description
1	PW	SHIELD	Shield
2	O	N_XD0	Negative LVDS Output, CameraLink Data D0
3	O	N_XD1	Negative LVDS Output, CameraLink Data D1
4	O	N_XD2	Negative LVDS Output, CameraLink Data D2
5	O	N_XCLK	Negative LVDS Output, CameraLink Clock
6	O	N_XD3	Negative LVDS Output, CameraLink Data D3
7	I	I_SERTOCAM	Positive LVDS Input, Serial Communication to the camera
8	O	N_SERTOFG	Negative LVDS Output, Serial Communication from the camera
9	I	N_CC1	Negative LVDS Input, CC1
10	I	N_CC2	Positive LVDS Input, CC2
11	I	N_CC3	Negative LVDS Input, CC3
12	I	P_CC4	Positive LVDS Input, CC4
13	PW	SHIELD	Shield
14	PW	SHIELD	Shield
15	O	P_XD0	Positive LVDS Output, CameraLink Data D0
16	O	P_XD1	Positive LVDS Output, CameraLink Data D1
17	O	P_XD2	Positive LVDS Output, CameraLink Data D2
18	O	P_XCLK	Positive LVDS Output, CameraLink Clock
19	O	P_XD3	Positive LVDS Output, CameraLink Data D3
20	I	N_SERTOCAM	Negative LVDS Input, Serial Communication to the camera
21	O	P_SERTOFG	Positive LVDS Output, Serial Communication from the camera
22	I	P_CC1	Positive LVDS Input, CC1
23	I	N_CC2	Negative LVDS Input, CC2
24	I	P_CC3	Positive LVDS Input, CC3
25	I	N_CC4	Negative LVDS Input, CC4
26	PW	SHIELD	Shield
S	PW	SHIELD	Shield

Table A.3: Pinout CameraLink connector

B

Revision History

Revision	Date	Changes
1.0	August 2005	First release
1.1	Oktober 2005	Removed USB model, separated into new manual.